THE
Post Office Electrical Engineers' Journal

PHOTOTELEGRAPHY.

E. S. Ritter, M.I.E.E.

In the October, 1928, number of this Journal a brief description was given of the "Belin," "Bell," and "Siemens-Karolus" systems. Since then a number of British newspapers have brought into use one or other of the three systems. The Siemens-Karolus system is in use in Japan by two newspaper companies, and the Australian Post Office has also a service between Melbourne and Sydney. The Belin system is in use between Pekin and Mukden in China. In the United States, the Bell system has a service between New York, Boston, Atlanta, Cleveland, Chicago, St. Louis, San Francisco and Los Angeles. On the continent of Europe a public service is available between Berlin, Frankfort-on-Main, Copenhagen, Vienna and Stockholm, using the Siemens-Karolus apparatus. The rates, charged per 100 square centimetres, which is the minimum charge, are approximately as follows; the charge for larger sizes per square centimetre up to a maximum of 18 by 25 centimetres being one hundredth of the minimum charged for one hundred square centimetres. Triple rates are charged for urgent messages and a slight reduction for messages sent after 7 p.m.

	Min. Size. 100 cm²	*Full Size.* 450 cm²
Berlin-Frankfort	4/-	18/-
Berlin-Copenhagen	10/-	45/-
Berlin-Stockholm	12/-	54/-
Berlin-Vienna	10/-	45/-
Frankfort-Copenhagen ...	12/-	54/-
Frankfort-Stockholm	14/-	63/-
Frankfort-Vienna	10/-	45/-

The British newspapers using photo-telegraphy transmit to and from London and their provincial offices, using "Four-Wire" telephone circuits rented from the Post Office as private wires, either for 24-hour service or in other cases for 12-hour service from 6 p.m. to 6 a.m. Where the paper has more than one provincial office it is usual to transmit simultaneously from London to the other offices. The newspapers also link up with associated offices on the Continent, using the same system over the public trunk lines; for example, those using the Belin system link up with Paris. Those using Siemens system connect with Milan, Hamburg, Paris, Berlin, Copenhagen, Frankfort, Stockholm (the last three stations being also open for public service), whilst in the case of Berlin there are two private installations, as well as that at the German Head Telegraph Office.

The Post Office has installed a Siemens-Karolus set in G.P.O. (West) for public service between London and Berlin. The service has since been extended to Frankfort and Copenhagen and may also be extended to Vienna and Stockholm should the demand arise. The apparatus is also used for a private service to a news agency in Paris fitted with similar apparatus. Since the opening of the service, the amount of traffic has been relatively small, but there are signs that it is on the increase. So far, it has been almost exclusively used for news pictures, but there are possibilities that it may

be used for sending written messages, code and cypher where accuracy is of importance, diagrams and plans, and also financial statements which are difficult to telegraph in the ordinary way. The charges to Berlin and Frankfort are for a minimum of 96 square centimetres £1, and for each square centimetre above, 2½d.; making a charge of £4 13s. 9d. for the maximum size of 18 by 25 centimetres containing an area of 450 square centimetres. To Copenhagen the charge is £1 4s. 0d. for 96 square centimetres and 3d. per square centimetre additional for larger sizes. The Berlin and Frankfort services are open from 7 a.m. to 11 p.m. weekdays and 3 p.m. to 11 p.m. Sundays, whilst that to Copenhagen is open 7 a.m. to 9 a.m. and 6 p.m. to 11 p.m. weekdays and 6 p.m. to 11 p.m. Sundays, the restricted hours in the latter case being due to the small number of trunk lines available for the service.

A brief description of the apparatus installed may be of interest. The installation (see Fig. 1) consists of a sender, a receiver and a two-bay control rack supplied by Siemens and Halske; a Power Switchboard constructed by the Central Telegraph Office Engineering Section, London District, to plans prepared by the Engineer-in-Chief's Research Section, and also the necessary batteries of secondary cells (see Fig. 2) laid out and installed in a like manner in an adjacent room. The switchboard provides charging facilities for anode batteries of 220-240 volts, filament or heating batteries of 12-14 volts, and photo-cell and grid bias batteries of various voltages contained in a lead-lined earth screened cupboard. The 12-volt filament battery is

FIG. 1.—POWER SWITCHBOARD, SENDING MACHINE, CONTROL RACK, RECEIVING MACHINE.

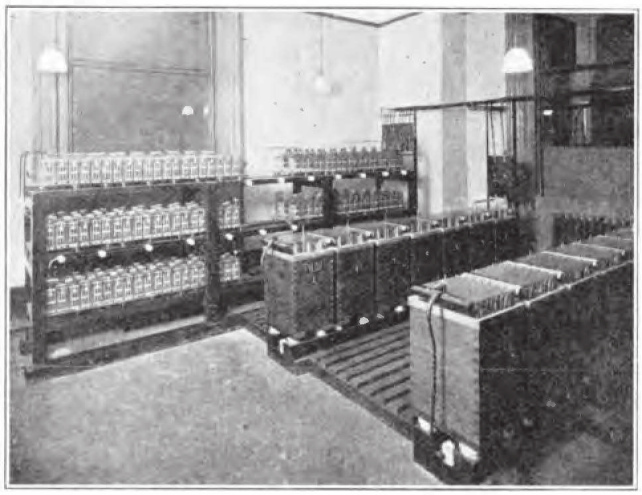


FIG. 2.—FILAMENT AND ANODE BATTERIES.

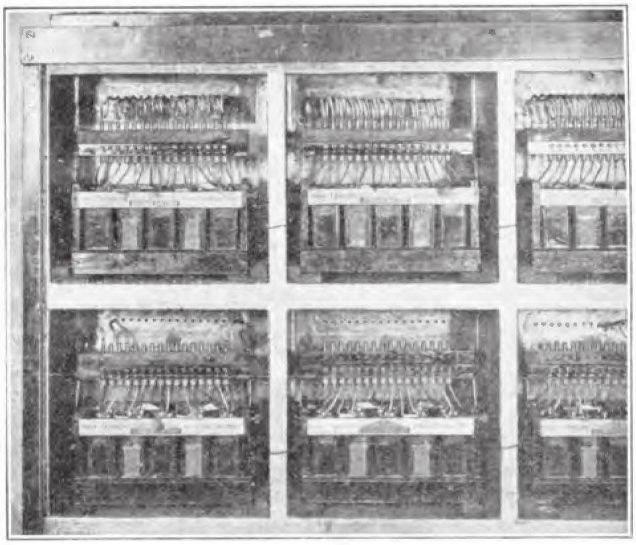


FIG. 3.—PHOTO-CELL AND GRID BIAS BATTERIES.

charged from a motor-generator, and is in duplicate, one battery being charged when the other is in use. There is an end cell switch fitted on each battery. The 220-volt anode battery is also in duplicate, and each battery is split into two halves to enable the charging to be done direct off the 220-volt D.C. mains. The mains also supply current for the tuning fork thermostat and heater, as well as the driving motors of the picture sender and receiver. The photo-cell batteries (see Fig. 3) are in 30-volt units tapped at every cell; each unit of 30-volts is interchangeable with every other unit and is taken out for charging purposes. In order to avoid a multiplicity of loose wires, an ebonite

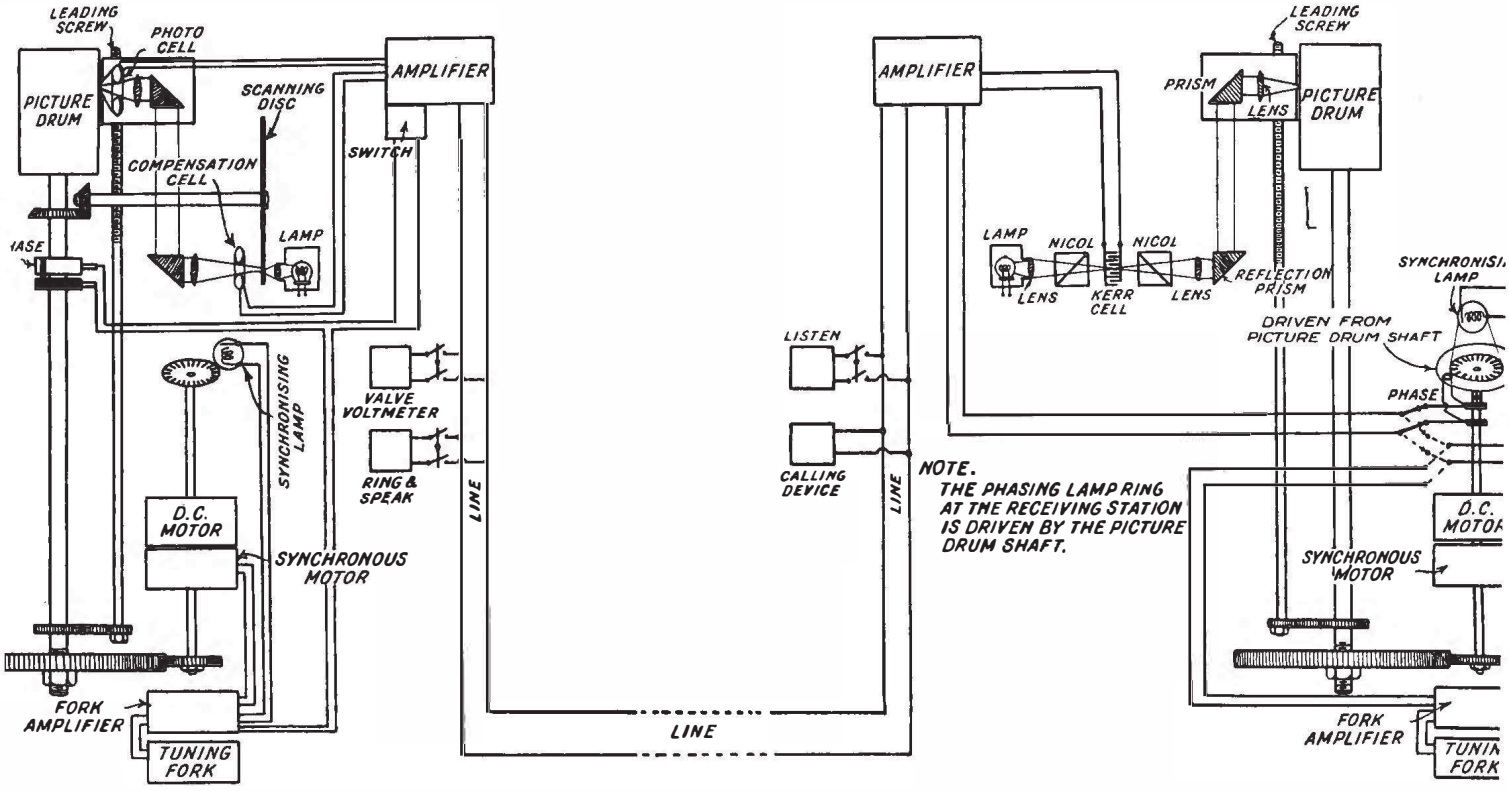


FIG. 4.—SCHEMATIC DIAGRAM.

strip on top of each unit has been fitted with 16 brass connecting sockets with brass locking screws, each connecting socket going to the junction of two cells by a soldered connection. Pins mounted on another ebonite strip fit into the sockets; the pins are soldered to the wires going to the switchboard. To replace a unit it is only necessary to loosen the screws, withdraw the top strip with the pins, take out the accumulator unit, replace with another unit, press in the top strip and tighten the screws. The ebonite strips have been accurately drilled and all are interchangeable; all exposed parts are carefully covered with vaseline. With the exception of the photo-cell battery, all the cells are topped with a mineral oil which prevents acid spraying during charging.

The Picture Apparatus.

A tuning fork of 1020 cycles per second, kept at a constant temperature by an electric heater controlled by a thermostat, is driven by a valve and its tone amplified and supplied to the stator of an inductor alternator, of which there is one in the sender and one in the receiver; in addition, fork tone is supplied to light a " neon " lamp above a stroboscopic disc in both sender and receiver. A D.C. motor drives the sender and is kept in synchronism by the alternator on the same shaft. The picture drum is driven by a gear from the motor shaft. Light from a gas-filled lamp similar to that used for automobile headlights is interrupted by a revolving disc with holes or teeth on its periphery and a light spot is focussed on the rotating picture drum, whence it is reflected back into a photo-cell, Fig. 5. As the drum rotates, the light spot and photo-cell are moved either up or down parallel to the axis of the picture drum by a lead screw at the rate of a fifth of a millimetre per revolution. By means of a gear-changing lever, this traverse may be changed to either a quarter of a millimetre or a third of a millimetre per revolution of the picture drum. The photo-cell originates an electric current proportional to the light falling on it; this current when amplified is sent over the telephone line. The light being interrupted, the current is an alternating one, having a frequency corresponding to the light interruptions and an amplitude proportional to the light and shade of the picture.

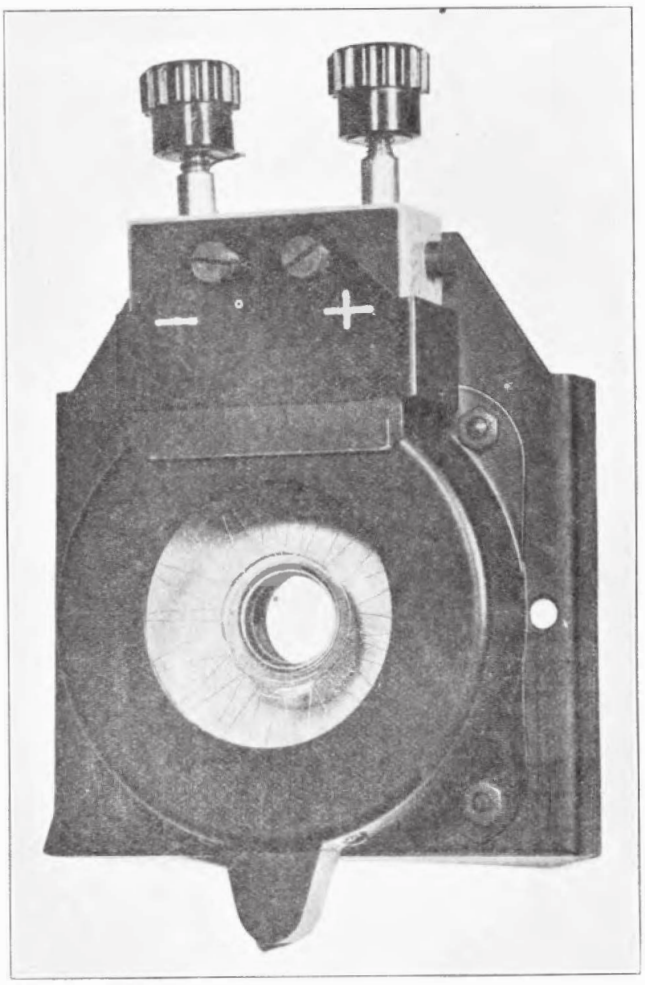


Fig. 5.—Photo Cell.

To compensate for the characteristics of the receiving equipment, it is desirable when sending a tone picture such as a photograph, to send, say, one volt to line for white and about one fourth of a volt for black, instead of one volt for white and nothing for black as would be the case if the arrangement was exactly as described above. In order to do this, a second photo-cell is placed in the path of a portion of the interrupted light beam so that it receives a constant amount of interrupted light. The amount of this light is so adjusted that the " compensation " photo-cell produces a quarter of a volt of amplified current. The two photo-cells act on the same amplifier in such a way that their outputs add and this accomplishes the desired result. In addition, a further facility is provided, should a positive picture be required at the receiving end instead of a negative, by arranging the com-

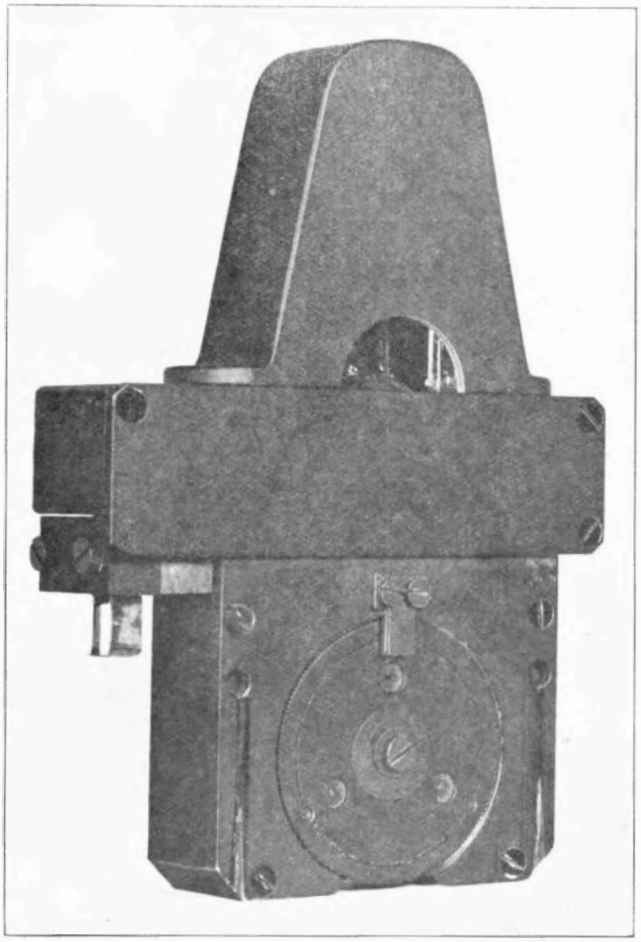


FIG. 6.—KERR CELL. BACK VIEW SHOWING APERTURE.

pensation cell to give an output of one volt of amplified current and connecting the picture cell so that its output subtracts from the output of the compensation cell the required result is obtained, namely, one volt for " black " on the picture and a quarter of a volt for " white."

The interruptor or carrier frequency is about 1100 cycles per second, but by changing the discs and using others with different numbers of holes other frequencies may be produced.

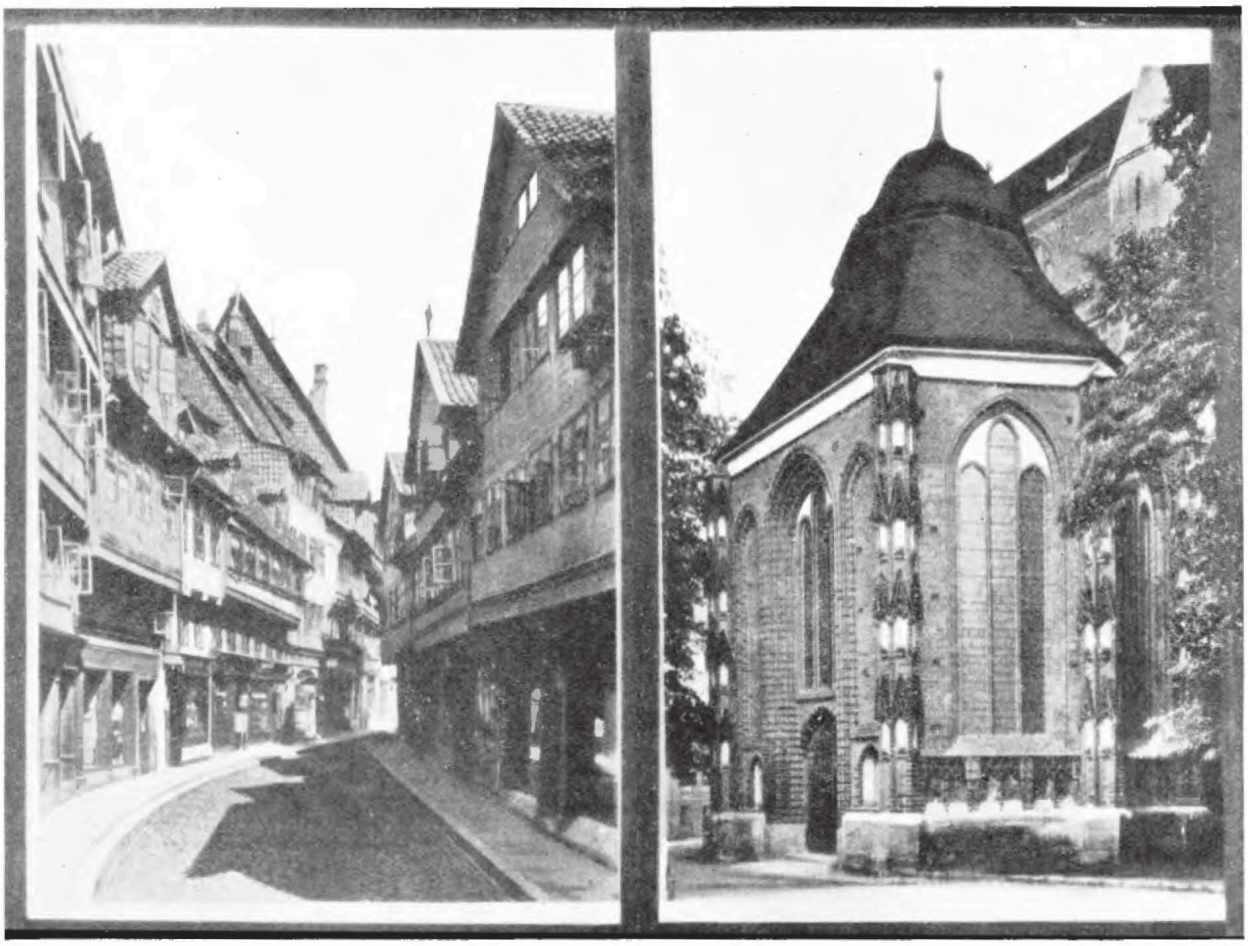
At the receiving end a drum driven in the same manner as the picture drum at the sending end has a photographic film clipped to its circumference. A light spot is focussed on the film and traverses it at the rate of a fifth of a millimetre per revolution (or a quarter or a third of a millimetre by gear change to correspond with the sender if required). The light spot, produced by a similar lamp to that at the sending end, is controlled in intensity electrically by the amplified current received from the line. The light from the lamp is passed through an optical system, which includes a nicol prism to polarise the light, then between the plates of a " Kerr " or " Karolus " cell (see Fig. **6**), which is a small electrical condenser immersed in nitrobenzol and sealed in a glass vessel, then through a second nicol prism and thence to the film in the form of a light spot. The amplified carrier current from the line is applied to the terminals of the condenser as an alternating current at a pressure of a maximum (for white sent) of about 700 volts.

The nicols are adjusted so that no light is passed with no voltage on the Kerr Cell; with a small increase of voltage very little light passes; for a further increase in voltage the light passed is proportional to the increase in voltage. Thus, when white or the maximum current is being sent, the maximum light falls on the film which, when developed, shows a black mark, producing a white mark on the printing paper. When black or minimum current is being sent, the compensation cell at the sending end is so adjusted that the voltage received is sufficient to operate on the Kerr Cell at the point where the light response is beginning to be proportional to the voltage received, and so one condition for correct tone reproduction is achieved. When no tone reproduction is desired, such as with diagrams or print, no compensation is sent, thus resulting in a sharper reproduction.

ADJUSTMENT OF SYNCHRONISATION AND PHASE.

In order to get the two machines to run at exactly the same speed, fork tone is sent over the line from the sender to the receiver. At the receiving end, it is connected to light the stroboscope lamp in place of the home fork tone, and the stroboscope is observed to see if the home fork is gaining or losing in comparison with that at the sending end. The home fork is adjusted by increasing or reducing the condenser reaction on the driving valve. Increasing the reaction has the effect of increasing the amplitude of the fork and slightly slowing it down, whilst decreasing the reaction has the reverse effect. The accuracy obtained is as follows: a gain of one sector in 50 seconds corresponds to a gain of one cycle in 100 seconds, a sector corresponding to half a cycle, or one hundredth of a cycle per

SPECIMENS OF PICTURES RECEIVED.



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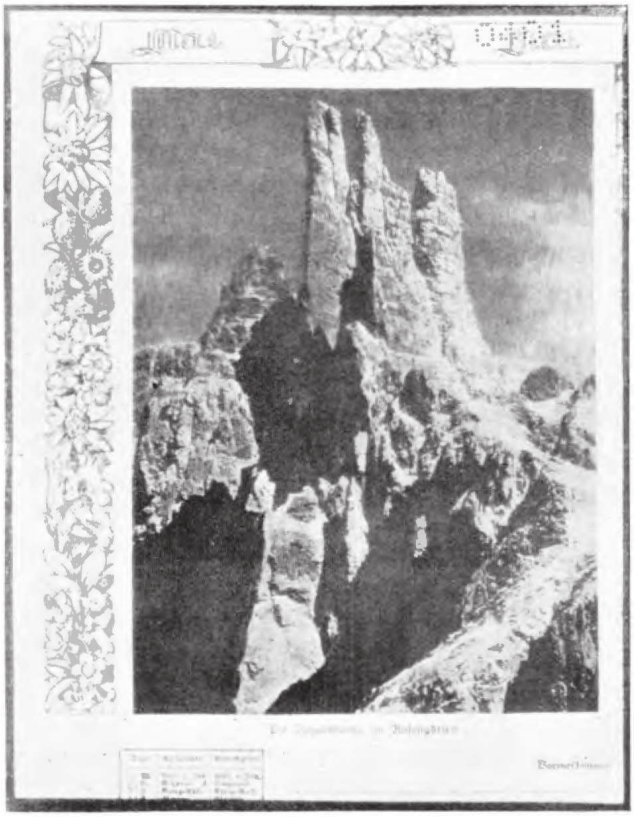


RECEIVED FROM VIENNA.

RECEIVED FROM COPENHAGEN.

second. Calling the fork frequency 1000 cycles per second (actually it is 1020 cycles) this corresponds to an accuracy of one cycle in 100,000 cycles; in practice an accuracy of one in 250,000 is worked to. Looked at another way, the length of the spiral scan of the picture is 813 feet approximately; at the receiving end a gain or loss of 0.04 of an inch is allowable.

In order to phase or set the sending and receiving drums in the correct relative position, a signal consisting of fork tone is sent over the line by a commutator once per revolution of the sending drum; at the receiving end this tone is used to light a neon lamp rotating at the same speed as the film drum. The receiving machine is adjusted so that this lamp lights opposite a given mark, indicating that the two drums are in the same relative position, taking into account automatically the propagation time of the line, which may amount to an appreciable portion of the drum circumference.

On the panels are mounted control voltmeters, etc., a telephone for speaking and a 500-cycle modulated by 20-cycle tone ringer and ringer receiver; space is left for fitting a second ringing receiver so that two lines may be operated simultaneously. The keys are interlocked to minimise as far as possible operating errors. Various fuses are provided in the circuits, as well as visible and audible alarm circuits. The machines can be set so as to run a full picture or a part as required. When the picture is finished an alarm lamp lights on the machine as an indication to the operator.

The setting up of the line sending fork tone, phasing and white should take not more than five minutes; running a full picture with a five line screen about 20 minutes, but if four line screen be used this could be done in 16 minutes. At the termination of the last picture, about four minutes is required so that the distant station may develop it far enough to see that it is O.K.

When a series of pictures have to be sent, the setting-up time between pictures need not exceed one or two minutes. The times given above are for expert operators at both ends; with inefficient operators at one or both ends these times will be largely exceeded. Under normal operation a picture handed in at Berlin should be delivered to the addressee in London within two hours.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31ST DEC., 1929.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
660,770	529	3,965	55,231	120	London	24,908	95,086	2,512,268	99,513
86,888	2,190	21,264	69,001	2,414	S. East	4,004	58,149	241,959	38,902
90,327	4,456	31,850	93,462	3,641	S. West	21,685	14,847	174,148	65,770
72,346	6,282	39,012	65,968	6,492	Eastern	24,446	46,321	153,059	64,310
104,801	8,450	45,205	62,947	4,606	N. Mid.	33,109	59,079	261,541	107,662
89,071	4,922	31,002	77,562	4,165	S. Mid.	12,219	29,305	210,126	83,273
61,624	4,744	50,018	56,661	3,422	S. Wales	6,682	28,942	137,586	70,157
113,869	7,978	26,575	53,789	4,507	N. Wales	13,794	42,939	304,708	61,078
168,553	1,469	15,695	44,903	3,269	S. Lancs.	14,645	83,273	533,280	51,027
98,869	6,212	30,302	48,741	3,528	N. East	13,342	46,929	264,208	74,036
68,289	3,891	23,961	40,132	2,775	N. West	8,477	36,323	177,119	29,465
50,922	2,556	16,046	26,739	2,862	Northern	7,326	20,073	142,429	40,615
23,034	4,493	8,904	13,952	584	Ireland N.	136	2,920	51,163	2,642
93,714	5,396	27,096	40,411	1,226	Scot. East	6,167	15,388	163,093	42,793
71,006	7,211	24,568	44,890	1,685	Scot. West	11,864	26,774	232,181	34,844
1,854,083	70,779	375,457	762,329	44,696	Total	202,804	606,348	5,558,868	866,093
1,822,328	71,058	374,341	748,532	41,975	Figures as at 30 Sept., 1929	202,006	588,075	5,441,522	873,241

AUTOMATIC EXCHANGES.

NEW STANDARD APPARATUS RACKS AND SHELF MOUNTING.

G. Brown, A.M.I.E.E.

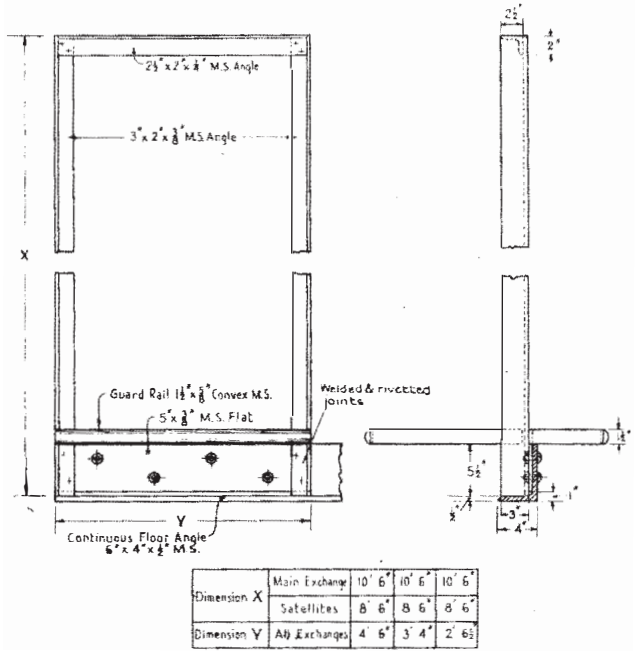
THE introduction of the Department's standard rack scheme will be responsible for some important changes in the disposition and appearance of Automatic Exchange equipment. The familiar Line Switch Unit with Preselectors on one side and Final Selectors on the other and the Selector Board, consisting of two 9′ $3\frac{1}{2}$″ racks back to back with a terminal assembly closing one end, will no longer be called for in new exchanges.

Arrangements are being made to adopt as standard, channel-shaped shelves of pressed steel for mounting apparatus and a racking scheme which will give greater flexibility of layout and better floor load distribution, at the same time making the fullest possible use of available building accommodation.

The adoption of a standard type shelf is important and has far-reaching effects. A feature of the shelf is that each complete selector or relay set is assembled as a separate unit on its own base; connection is made to the cabling through jack points on the shelf. The jack points will be rigidly standard and will result in various Contractors' apparatus being interchangeable as far as unit selectors and relay sets are concerned. Therefore, all apparatus will be on the units and detachable from the shelves. Only jacks and wiring will be permanently attached to the shelf.

Construction and Dimensions.—The design of the new standard has followed the lines of what is generally referred to as the "single-sided" rack scheme, similar to the racking arrangements which have been used for many years in P.O. Exchanges of Messrs. Siemens No. 16 type. The apparatus will be mounted on one side only, with wiring accessible from the rear.

British Standard Mild Steel Angle Sections will be used in the construction of the racks, the dimensions and details of which are shown in Fig. 1. An important change from present



Dimension X	Main Exchange	10′ 6″	10′ 6″	10′ 6″
	Satellites	8′ 6″	8′ 6″	8′ 6″
Dimension Y	All Exchanges	4′ 6″	3′ 4″	2′ 6½″

FIG. 1.—CONSTRUCTIONAL DETAILS OF RACK.

practice is the 6″ × 4″ × ½″ angle laid on the floor surface as a continuous footing under each suite of racks, for floor load distribution. The racks will be securely bolted to the floor angle and braced at the top by means of cable runways. Lengths of floor angle, sufficient for initial requirements only, will be laid at the outset and joints in the angle should not occur under the junction of two racks. As the weight of 6″ × 4″ × ½″ angle is a little over 16 lbs. per foot, it will be necessary to restrict the lengths for handling. A convenient arrangement for meeting these conditions, using five stock lengths, is shown in Fig. 2. Convex steel guard rails will be fitted at the front and rear of every rack as protection against damage to apparatus and wiring by portable equipment.

The racks will have a uniform height of 10′ 6″ in exchanges where a minimum clear height of 12′ is obtainable in the apparatus rooms. In exchanges where 12′ is not obtainable, the racks will be 8′ 6″ high. For subscribers' preselectors, all ranks of selectors, directors, coders, senders and relay sets, a 4′ 6″ wide rack will be used. Keysender " B " position apparatus requires a 3′ 4″ rack and alarm equipment apparatus 2′ 6¾″. It will be seen that the bulk of the apparatus will be on the same width of rack (4′ 6″) which should facilitate to some extent the preparation of floor plan drawings.

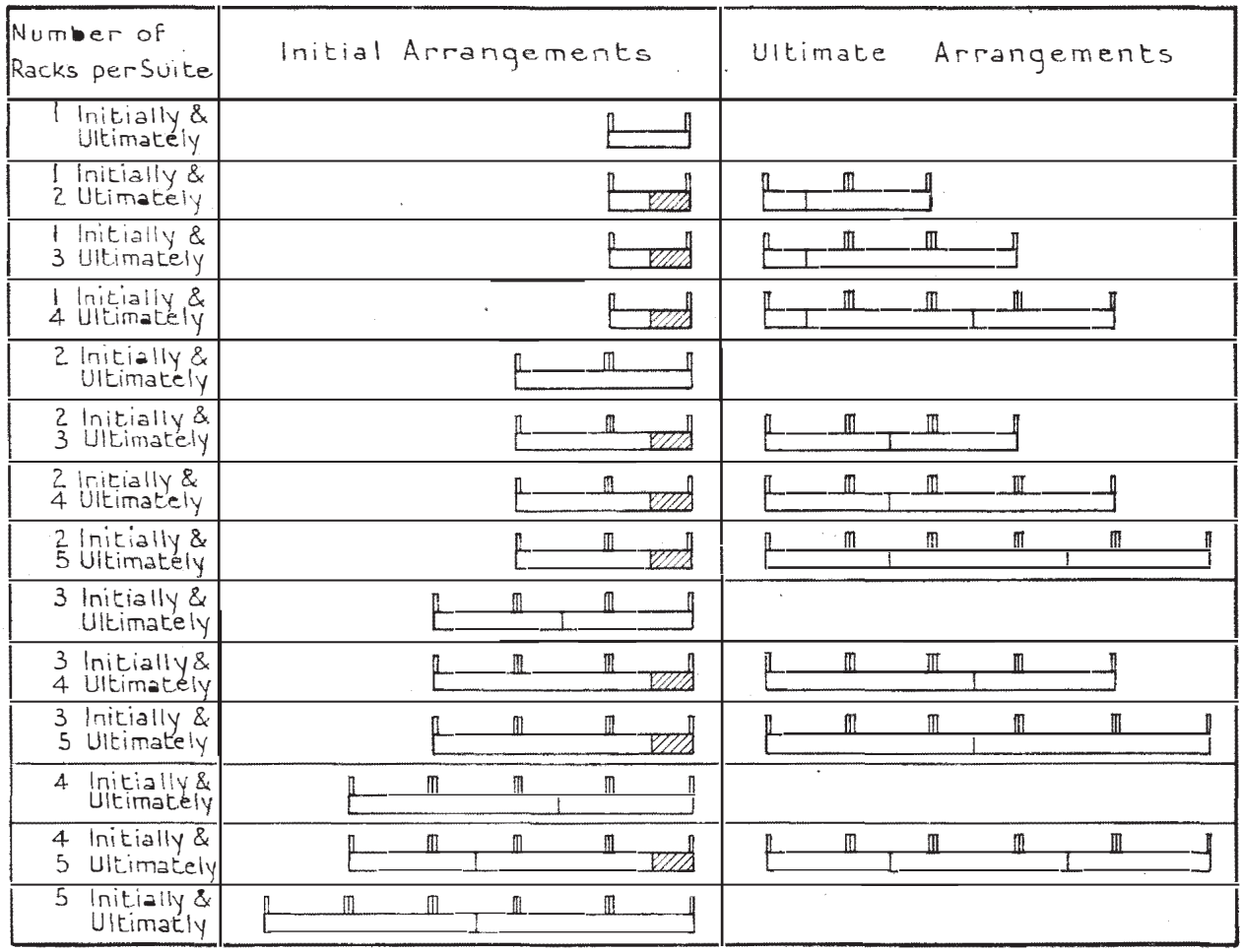

Number of Racks per Suite
Initial Arrangements
Ultimate Arrangements
1 Initially & Ultimately
1 Initially & 2 Ultimately
1 Initially & 3 Ultimately
1 Initially & 4 Ultimately
2 Initially & Ultimately
2 Initially & 3 Ultimately
2 Initially & 4 Ultimately
2 Initially & 5 Ultimately
3 Initially & Ultimately
3 Initially & 4 Ultimately
3 Initially & 5 Ultimately
4 Initially & Ultimately
4 Initially & 5 Ultimately
5 Initially & Ultimately

FIG. 2.—CONTINUOUS FLOOR ANGLES FOR 4′ 6″ RACKS.

Shelves.—The pressed steel channel type shelf has been developed by the Automatic Telephone Manufacturing Co., Ltd., Liverpool, and will be used with the standard racks for mounting all apparatus except preselectors. Fig. 3 shows a portion of a channel type shelf, looking at the front.

Three lengths of channel shelf will be used as follows :—

Length of Shelf.	No. of Switches per Shelf.	Width of Rack.
4′ 4⅞″	10	4′ 6″
3′ 2⅝″	7	3′ 4″
2′ 5⅛″	5	2′ 6¼″

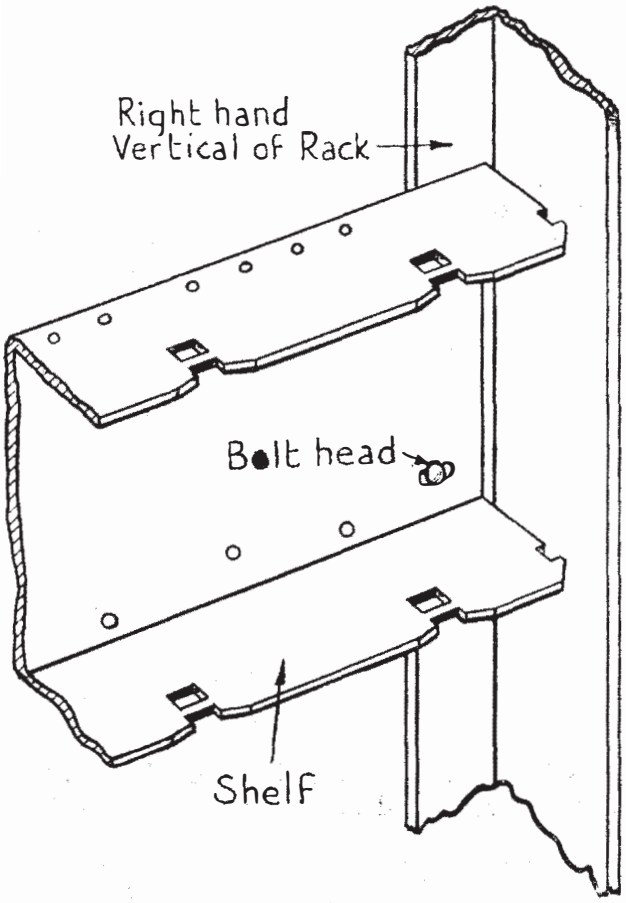


FIG. 3.—SECTION OF CHANNEL TYPE SHELF.

A typical arrangement of a 200 outlet group selector " jacked-in " on a channel type shelf is seen in Fig. 4, which also shows the method of terminating cables at the rear of the shelves.

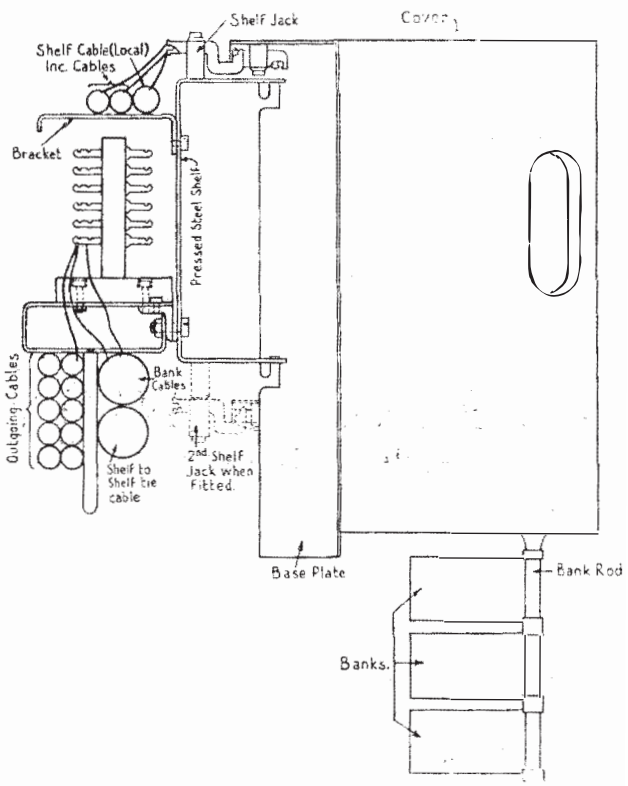


FIG. 4.—SECTIONAL VIEW OF SELECTOR SHELF AND CABLING CONNECTIONS.

Subscribers' preselectors will be mounted 20 per shelf on 4′ 6″ racks as in Fig. 5. Each shelf is a self-contained detachable unit of 20 preselectors, with associated line and cut-off relays and spark quench condensers. If required, an access switch for connecting routine test apparatus may be mounted in the first position on each shelf. Each preselector is carried on two anti-vibration springs as shown in Fig. 6.

A 5 × 20 connection strip is mounted on the left of the shelf for incoming cables. For outgoing cables there is another connection strip fitted on the right. The outgoing connection

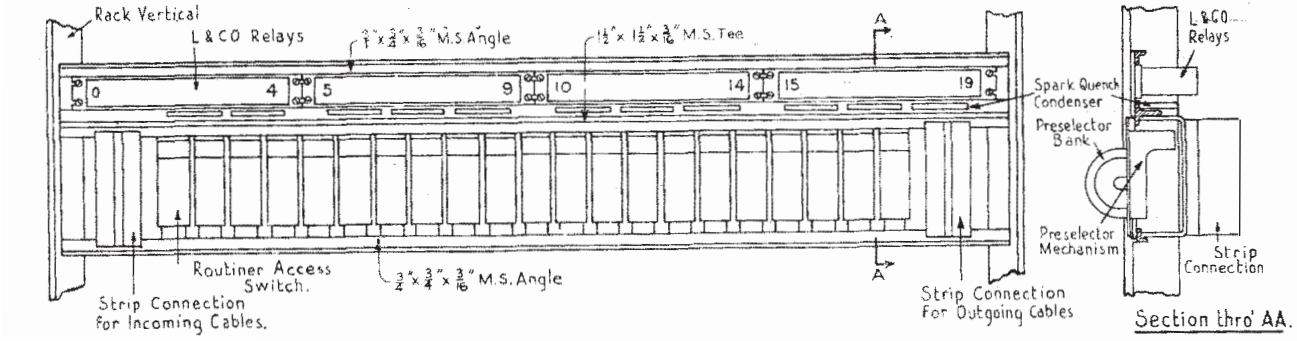


FIG. 5.—UNIT SHELF OF SUBSCRIBERS' PRESELECTORS.

strip will be 4 × 25 for Booster Battery and 5 × 25 for 4th wire metering systems. This arrangement allows in each shelf, on the outgoing side, a row of 20 tags for miscellaneous connections.

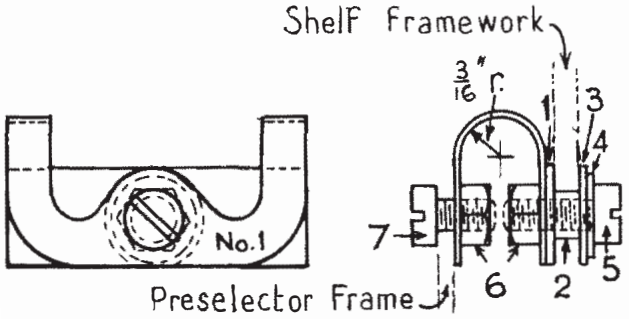


Fig. 6.—Anti-Vibration Spring for Preselectors.

Cabling.—A schematic diagram of the cabling for a single subscribers' line circuit is seen in Fig. 7. Between the M.D.F. and I.D.F., two wires per circuit will be provided for ordinary lines. In the case of P.B.X. lines, three wires are required as the " P " wire is extended to the main frame for " busying." Five wires per circuit are required from the local side of the I.D.F. to the preselector racks. The outlets from all ranks of selectors will be terminated on Trunk Distribution Frames. These frames are very similar in design to the I.D.F. with connection strips, 6 × 20 type, mounted vertically on the incoming side and 3, 4, or 5 × 20 type mounted horizontally on the outgoing side. Grading is carried out on the vertical connection strips, and the graded groups cross-connected to the outgoing cables which are terminated on the horizontal strips.

Disposition of Apparatus on Racks.—In the arrangement of the apparatus, consideration has been given to the possibility of damage to the bottom row of banks by men stepping on the guard rails. Reference to Fig. 8 shows the method of attaching the guard rails to the rack verticals. A clear 15" has been allowed normally between the floor and the bottom of the lowest piece of apparatus. In certain cases the clearance from the floor may be reduced to 12" to allow an additional shelf being fitted, but never less than 12". The bottom of the guard rail will be 6" from the floor so that there should be sufficient clearance to safeguard the bottom banks.

The fixing centres of the channel type shelves have been arranged to give a minimum clearance of 1½" between the top of the apparatus on one shelf and the bottom of the apparatus on the shelf above, wherever possible. This clearance is considered sufficient for the safe withdrawal of switch covers, and allows wiper cords to hang free.

Shelf designations are alphabetically arranged from the bottom upwards.

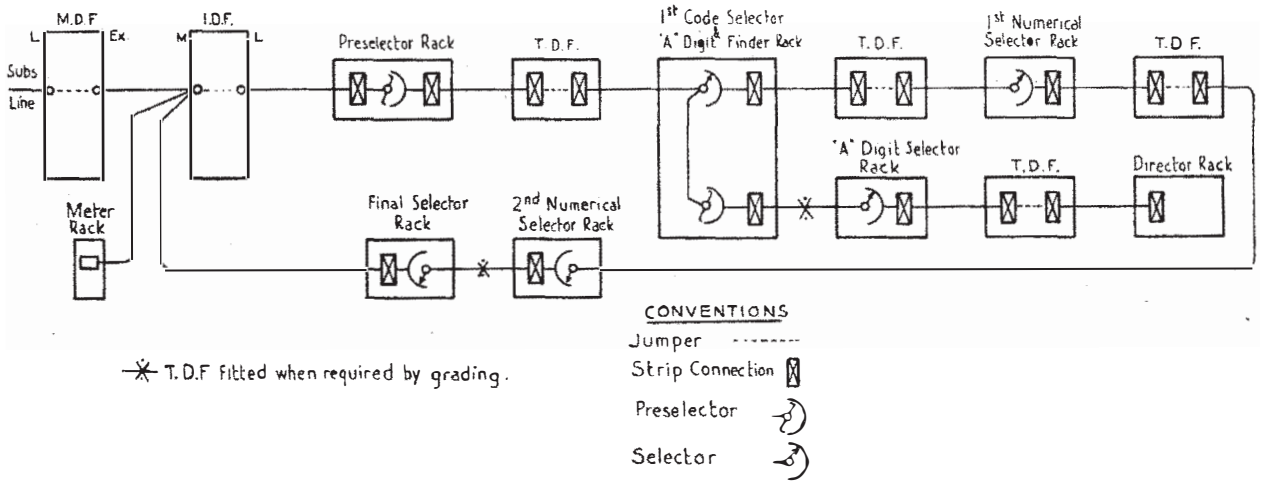


Fig. 7.—Schematic Cabling of Subscriber's Line Circuit.

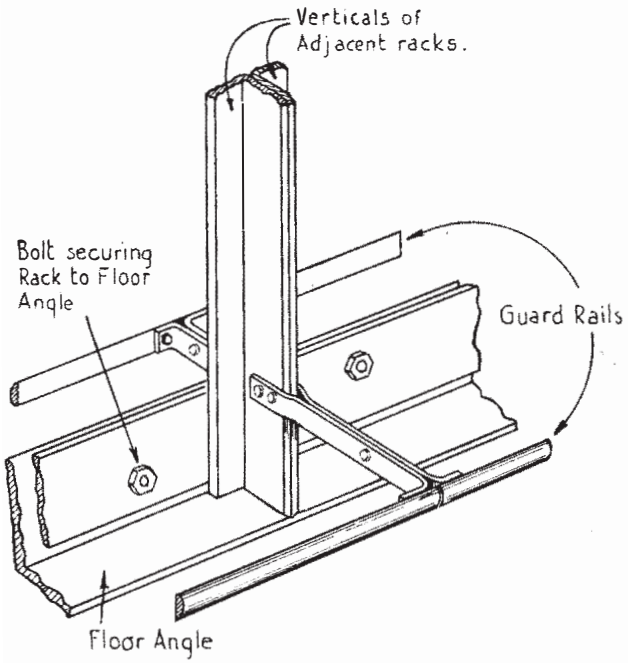


FIG. 8.—METHOD OF ATTACHING GUARD RAILS TO RACK VERTICALS.

Subscribers' Preselectors.—A fully equipped preselector rack is shown in Fig. **9**. Each shelf has its preselectors numbered 0 to 19 in addition to the number of the subscriber's line concerned. To locate a given subscriber's preselector, a reference to records will give the rack number, shelf letter and numerical position of the preselector, *e.g.*, 2468/PS—2/B5, indicating that the preselector of Subscriber No. 2468 is the 5th switch on shelf B of rack No. 2.

The outlets from this rack may be arranged in any grouping desired, in multiples of 20.

Group Selectors.—Fig. **10** shows a typical Selector Rack equipped with 6 shelves of 200 outlet selectors. Where 100 outlet selectors are used, 7 shelves may be mounted on a 10′ 6″ rack, as in this case the Selector has 2 banks, whereas the 200 Outlet Selector has 3 banks.

Referring again to Fig. **4**, an end view of a typical connection strip is seen, five of which are mounted at the rear of alternate selector shelves. Easy access to the soldering tags is provided by connecting the bank tails, outgoing cables and shelf tie cables to the same side of the connection strip. A general view of the cabling of a shelf of selectors equipped with connection strips is shown in Fig. **11**. The tie cables would, of course, only be provided if more than 20

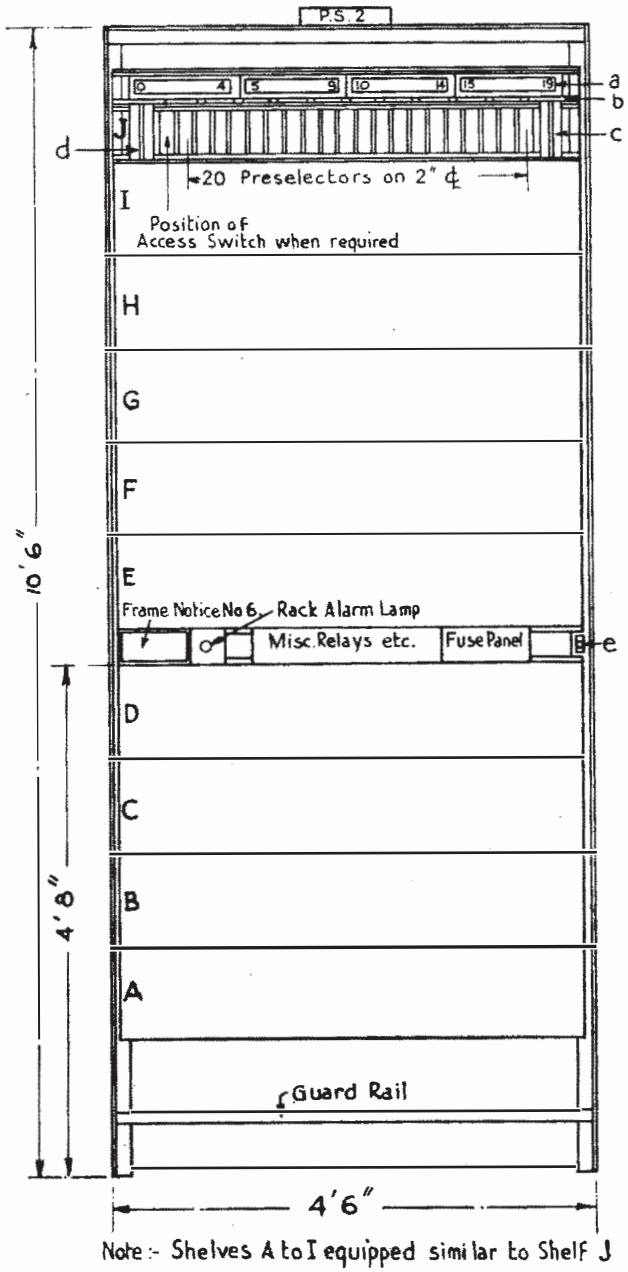
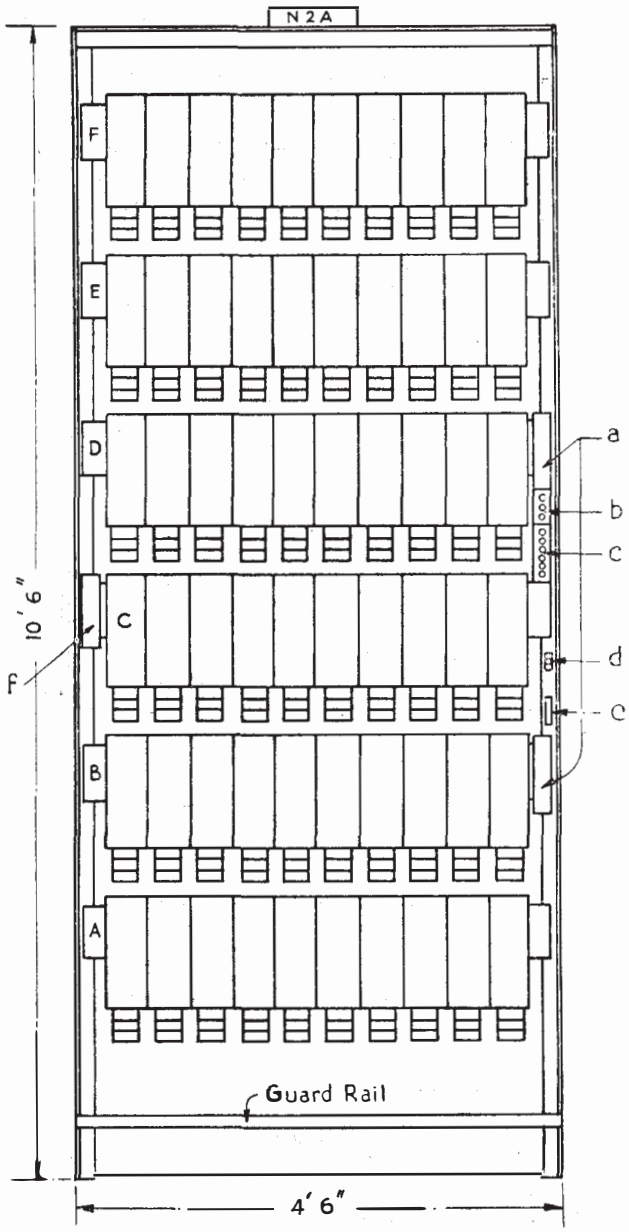


FIG. 9.—PRESELECTOR RACK.

selectors were grouped, or in the case of the 100 outlet selectors where the 7th shelf was grouped with a shelf in another rack. The outgoing cables are led away to the Trunk Distribution Frame. On the top of Fig. **4** will be seen the



a... Misc. Relays
b... Rack Alarm Lamps
c... Shelf " "
d... Battery Jack
e... Jack for Traffic Meters
f... Fuse Panel

FIG. 10.—RACK FOR GROUP SELECTORS (200 OUTPUT).

relatively small set of incoming cables connected to the shelf jacks.

1st Code Selectors.—Due to the circuit conditions involved, the base of a 1st Code Selector is $7\frac{1}{2}$" longer than that of an ordinary group selector, with the result that only 30 of the former and the associated " A " digit finders, can be accommodated on a 10' 6" rack. See Fig. **12**. Connection strips are fitted at the rear of each shelf so that groups of 10 selectors may be cabled out to the T.D.F., otherwise the arrangement of the bank tails and outgoing cables is similar to that of the group selectors.

The " A " digit finder banks are terminated on connection strips mounted alongside the finders.

Final Selectors.—Three types of final selectors are equipped on the 4' 6" rack. These are:—(*a*) 200 line and 2/10 P.B.X. finals, (*b*) 11/20 and over 20 P.B.X. finals, and (*c*) 100 line finals. The first two mentioned are mounted 50 per rack in five shelves of 10 and the 100 line finals are mounted 60 per rack in six shelves of 10, for 12' rooms.

Each final selector shelf, whether fully equipped or otherwise, will have its full complement of 32 point jacks fitted. Test and Trunk Offering final selectors may be mounted in any desired position.

A typical 200 line and 2/10 P.B.X. final selector rack is shown in Fig. **13**.

The shelves are equipped at the rear with five connection strips to each group and the method of connecting the bank tails and outgoing cables is similar to that described for the group selectors. The disposition of the 200 3-wire connections is shown in Fig. **14**. It will be seen that the 7th row of tags is commoned. This provides a means of connecting a 1300 ohm spool or relay to the " private " of any spare or unallotted line joined to " N.U. Tone." A 3 × 20 connection strip is fitted (1 per rack) to provide auxiliary connections when the number of lines

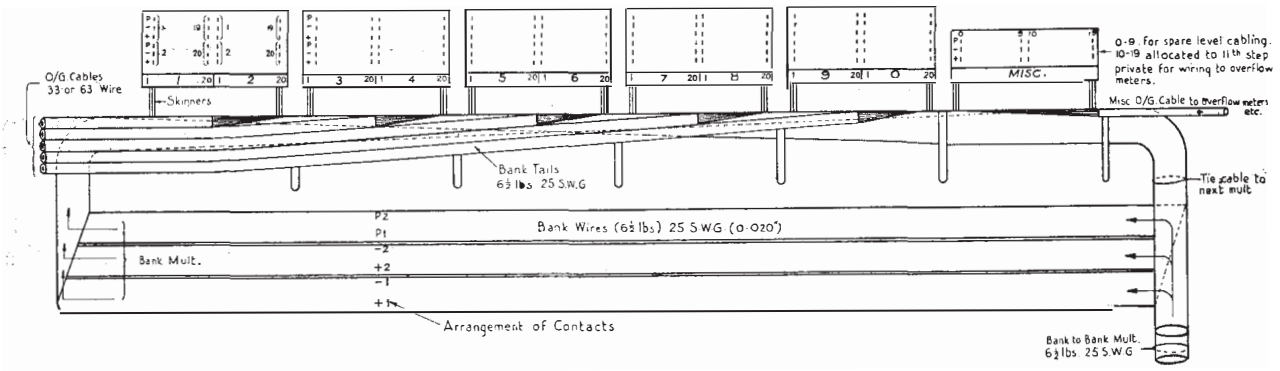
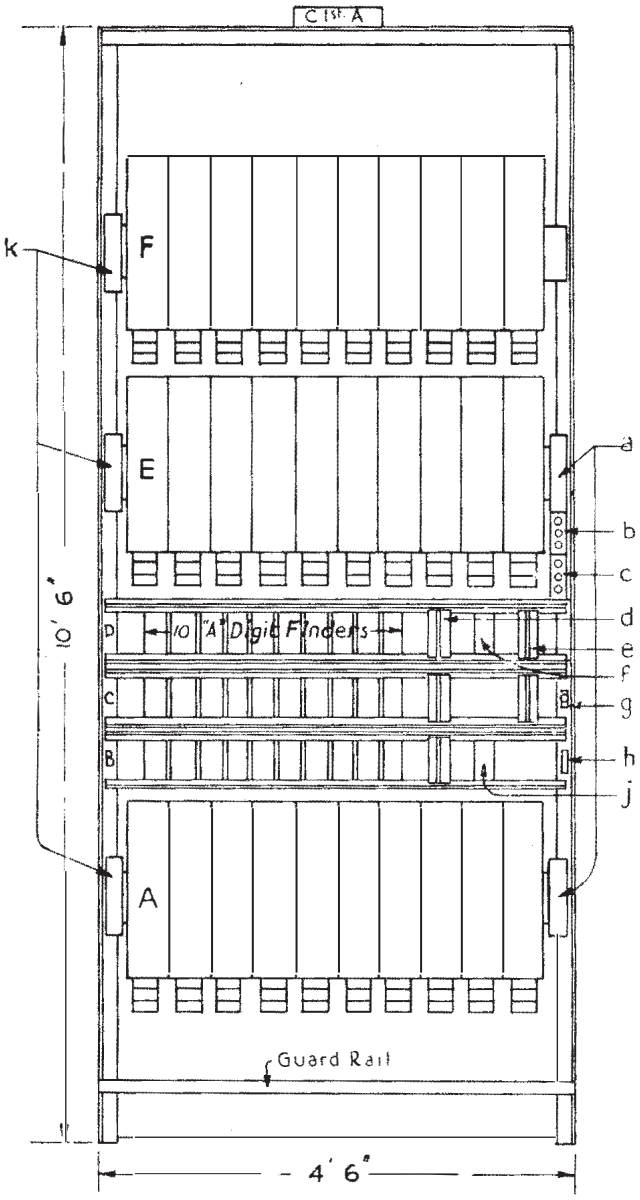
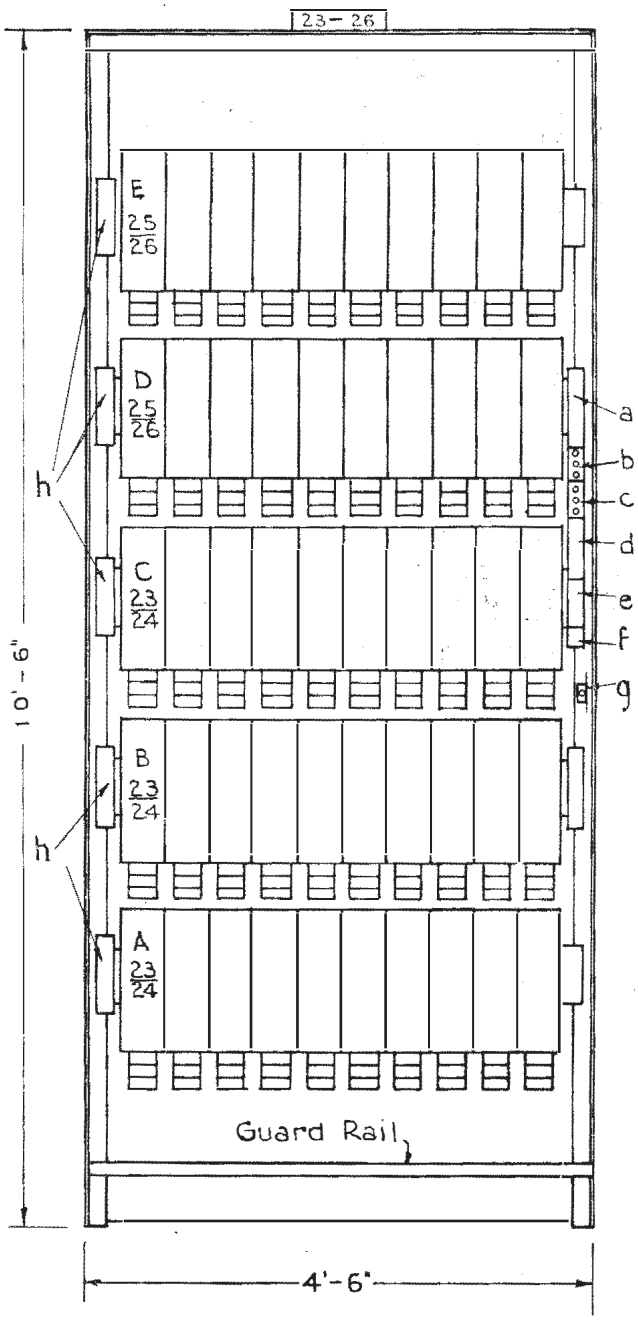

O/G Cables 33 or 63 Wire
Skinners
MISC.
0-9. For spare level cabling.
10-19 allocated to 11th step private for wiring to overflow meters.
Misc O/G Cable to overflow meters etc.
Bank Tails 6½ lbs. 25 S.W.G
Tie cable to next mult
Bank Wires (6½ lbs.) 25 S.W.G (0·020")
Bank Mult.
Arrangement of Contacts
Bank to Bank Mult. 6½ lbs. 25 S.W.G

FIG. 11.—GENERAL VIEW OF SELECTOR SHELF CABLING.



a... Misc Relays
b... Rack Alarm Lamps.
c... Shelf Alarm Lamps
d... Strip Conn. for "A" Digit Finder Outlets.
e... " " " Access Switches
f... Routiner Access Switch for Shelves E & F
g... Battery Jack
h... Jack for Traffic Meters
j... Routiner Access Switch for Shelf A
k... Fuse Panels.

FIG. 12.—FIRST CODE SELECTOR RACK.



a... Misc. Relays.
b... Rack Alarm Lamps.
c... Release Alarm Lamps.
d... Test Jacks.
e... Links for Busy etc.
f... Screw Terminals.
g... Battery Jack.
h... Shelf Fuse Panels.

FIG. 13.—RACK FOR FINAL SELECTORS (200 LINE).

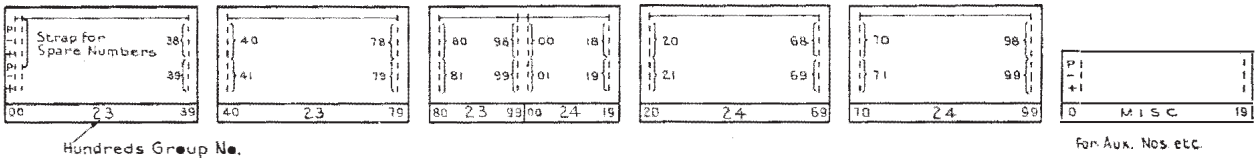
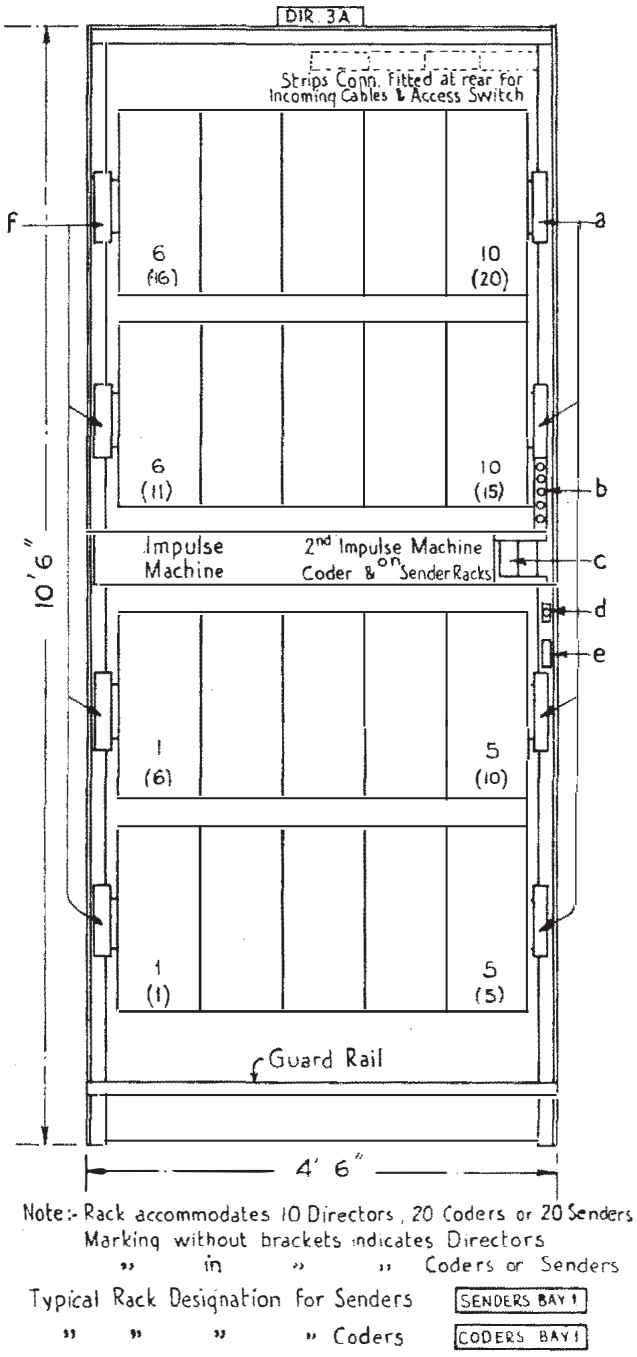


FIG. 14.—FINAL SELECTOR MULTIPLE TERMINATION.



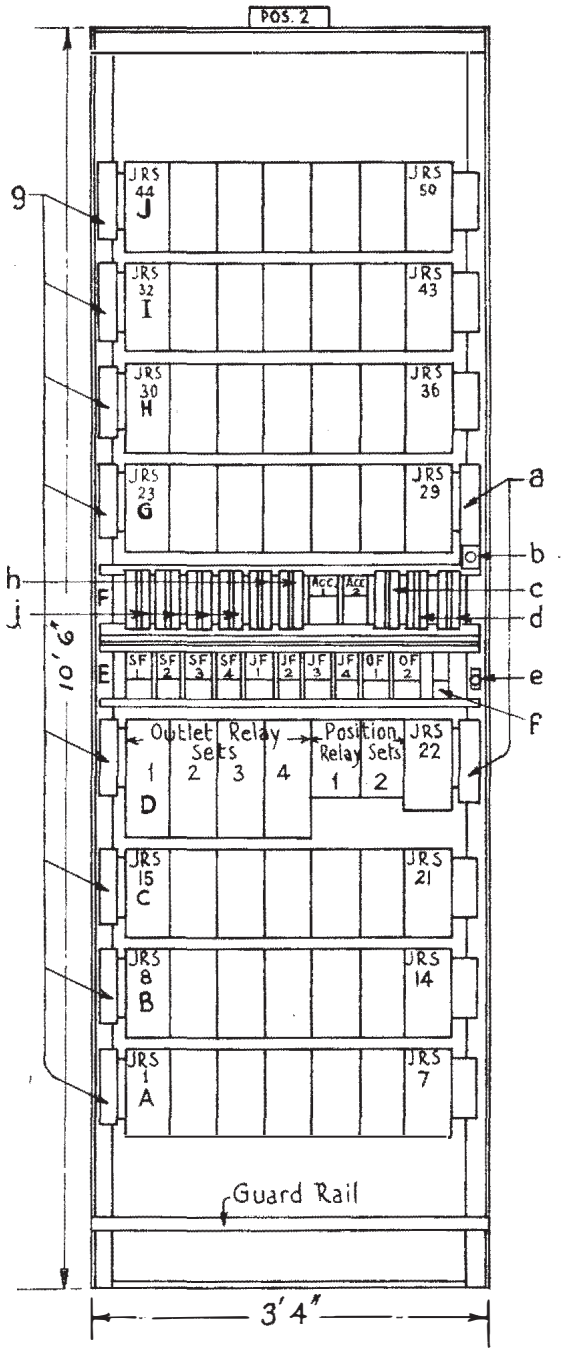
Note:- Rack accommodates 10 Directors, 20 Coders or 20 Senders
Marking without brackets indicates Directors
" in " " Coders or Senders

Typical Rack Designation for Senders SENDERS BAY 1
" " " " Coders CODERS BAY 1

a... Misc Relay
b... Rack Alarm Lamps
c... Routiner Access Switch
d... Battery Jack
e... Jack for Traffic Meter
f... Fuse Panels

FIG. 15.—RACK FOR DIRECTORS, CODERS OR SENDERS.

on a P.B.X. exceeds 10. There is also a miscellaneous power connection strip at the top rear of each rack.



a... Misc. Relays
b... Rack Alarm Lamp
c... Strip Conn. for Access Switch
d... " " " Misc
e... Battery Jack
f... O.W. Tone Preselector
g... Fuse Panels
h... Strips Conn. for Junction Finder Outlets
j... " " " Sender " "

FIG. 16.—KEYSENDER " B " POSITION APPARATUS RACK.

Directors, Coders or Senders.—A 4′ 6″ rack mounts 10 Directors (Fig. **15**). The components of the Director are assembled in two parts, each on its own base. Part 1, consisting of the "B.C." switch and the translation field, is mounted above the digit registers forming Part 2. 20 coders or 20 senders may be mounted, five per shelf, on the 4′ 6″ rack.

Keysender "B" Position Apparatus.—The relay sets, junction finders and sender finders required for the junction circuits connected to a Keysender "B" position will be mounted on a 3′ 4″ rack, as in Fig. **16**. One rack is, therefore, required for each equipped junction position of this type.

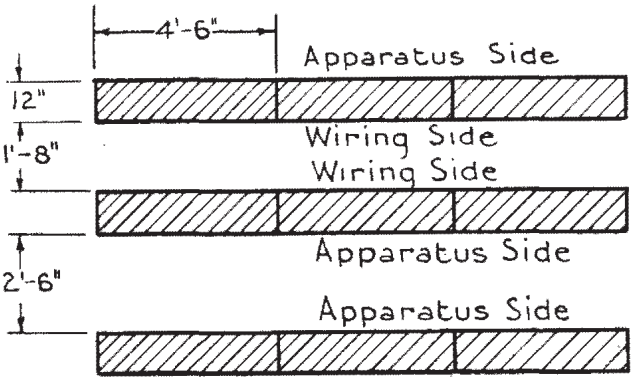


FIG. **17.**—RACK LAYOUT SHOWING GANGWAY.

General.—The racks described in the preceding paragraphs are typical and will perhaps suffice to give a general idea of the scheme.

Power will be served to the apparatus from vertical bus bars fixed on the left of every rack. Small fuse panels, fitted with alarm fuses and varying in number according to the battery connections required, will be associated with the bus bars. Each rack will be provided with fuse alarm lamps fitted on the right hand vertical. Miscellaneous relays, battery jacks, test jacks, etc., will also be mounted on the right hand verticals, space being provided at the end of the channel type shelves for mounting this apparatus.

No mention has been made of racks for meters, routiners, special apparatus or test jack frames, as the present construction of these will not be affected, except for changes of minor consequence necessary to make them fit in with the cabling arrangements.

The following schedule gives the capacities of the principal racks to be used:—

Type of Rack.	No. of sets per Rack.	
	12′ Rooms.	10′ & 11′ Rooms.
Preselectors	200	160
Selectors. Group 200 outlet ...	60	50
,, ,, 100 ,, ...	70	50
,, Final 200 line ...	50	40
,, ,, 100 line ...	60	40
,, ,, P.B.X. 11/20	50	40
,, ,, ,, over 20	50	40
,, 1st Code single metering with "A" digit finders ...	30	20
,, 1st Code excess fee metering with "A" digit finders ...	30	20
,, "A" Digit ...	70	50
,, Discriminating ...	40	30
,, Discriminating and Group Selectors	—	20 + 20
Directors	10	—
Coders	20	—
Senders	20	—
Relay Sets. 10 relays per base	120	100
,, ,, 12 ,, ,, ,,	110	90
,, ,, 14 ,, ,, ,,	100	70
,, ,, C.C.I. & Coder finders	120	—
,, ,, C.C.I. & Coder finders (Tandem)	70	—
Keysender B. 50 Junc. R.S. & Appt. for 1 position ...	1	—

The new racks will be installed in suites with apparatus sides face to face so that alternate apparatus and wiring gangways are formed, as in Fig. **17**. The minimum permissible width for an apparatus gangway is 2′ 6″ clear and 1′ 8″ clear for a wiring gangway.

As the racks in 12′ rooms will be 10′ 6″ high, ladders will be required to provide access to the upper shelves for maintenance. Several proposals are now being investigated with a view to determining the most suitable design of ladder for the purpose.

It will be appreciated from the following table of weights that considerable floor-loads are carried by modern Automatic Exchange buildings. In some recent cases the floors have been designed to carry a load of 2 cwt. per square foot, but as the limits of weight will be known for the standard racks it may be possible in future to reduce that to a lower figure, say 1½ cwt. per

square foot, with safety and consequent percentage reduction in the cost of building steelwork.

Estimated weights of typical fully equipped Standard Racks :—

10′ 6″ Racks for :	Weight in lbs.				
	Framework including Guard Rails.	Apparatus	Cabling and Wiring.	Floor Angle.	Totals.
Subscribers Preselectors ...	202	858	150	73	1283
Group Selectors (200 Outlet) ...	,,	1275	,,	,,	1700
Group Selectors (100 Outlet) ...	,,	1175	,,	,,	1600
1st Code Selectors	,,	825	,,	,,	1250
"A" Digit Selectors	,,	1175	,,	,,	1600
Final Selectors (100 Line) ...	,,	1315	,,	,,	1740
Final Selectors (200 Line) ...	,,	1175	,,	,,	1600
Directors	,,	575	,,	,,	1000
Relay Sets (General)	,,	1325	,,	,,	1750
Relay Sets (C.C.I.)	,,	1175	,,	,,	1600
Keysender "B" Apparatus ...	185.5	608	,,	56.5	1000

In conclusion, it is anticipated that as direct results from the use of the racks described, there will be greater flexibility of layout and economy of floor space due to the increased height of the racks and the fact that effective use is made of their full capacity for mounting apparatus. There is also the possibility of lighter floor construction due to better distribution of floor loads.

As the racks will be of uniform design, extensions of exchange equipment may be carried out with greater facility and installation time may ultimately be reduced due to the number of standard units that can be assembled, wired and tested in the factories.

The first contracts to be carried out with Channel Type Shelves will be for the Bristol Area and Acorn (London), although in the former case a different type of Preselector Rack assembly has been agreed for manufacturing reasons.

Many useful discussions with mutual advantage have taken place between Contractors' representatives and members of the Engineer-in-Chief's Staff while the scheme was developing. Appreciation is due to the Engineers of the undermentioned firms for their helpful co-operation and generously contributed data :—

Automatic Telephone Manufacturing Co. Ltd.
Standard Telephones & Cables, Ltd.
Siemens Bros., Ltd.
The General Electric Co., Ltd.
Ericsson Telephones, Ltd.

The writer is also indebted to Mr. S. A. Waters, of the Engineer-in-Chief's Office, for valuable assistance in preparing the diagrams and sketches for this article.

SOUTHEND-ON-SEA MULTI-EXCHANGE AREA.

C. A. MITCHELL and S. G. LAST.

THIS rapidly growing area embraces ten exchanges and it was the intention that seven of these should be changed over to Automatic working simultaneously. Owing to accommodation difficulties, however, one of them, namely Great Wakering, had to be left in abeyance. The other three exchanges in the area are to remain manual, on a dialling-in and dialling-out basis, until economic considerations warrant conversion. The dialling-out codes consist of the first two digits of the five figure numbers allotted to the exchanges in the trunking scheme. Thirteen other exchanges, outside the multi-exchange area, dial-in to Southend.

The cut-over took place at midnight on 27th April, 1929. The operations, from the commencement of the disconnection of the old exchanges to the completion of the cut-in of the six new exchanges, occupied six minutes. Apart from the fact that certain P.B.X. night extension arrangements had been left incorrectly connected by a subscriber, thus giving rise to permanent loops on the exchange lines concerned, no trouble was encountered.

The following exchanges were closed down :—

Name.	System.	No. of Positions.
Southend Main and 1st Relief	Magneto Multiple ...	19
Southend 2nd Relief...	C.B. No. 10 ...	12
Leigh-on-Sea ...	Magneto multiple ...	9
Thorpe Bay	C.B.S. No. 2 ...	3
Rochford	Magneto	2
Hadleigh, Essex ...	Village Auto ...	—
		45

Brief particulars of the new conditions are shown in the accompanying schedule.

Name.	Multiple		Trunk Ends.	Junction Ends					Numbering Scheme.	Subs. cut over	
	Equipped	Capacity		Auto to Auto	Auto to M.Bd.	M.Bd. to Auto.	Signal-ling	D/I & D/O		Exch. Lines	Stations
Southend-on-Sea	3,200	6,000	59	312	86	37	—	56	2000-4899, 49000-49299	1983	2789
Leigh-on-Sea ...	2,100	4,500	—	110	32	14	—	—	7100-7499, 75000-76699	1045	1252
Marine	1,500	3,200	—	95	29	11	—	—	6100-6699, 67000-67899	704	979
Thorpe Bay ...	800	1,800	—	49	13	5	—	—	8100-8799, 88000-88099	366	382
Hadleigh ...	500	1,200	—	32	10	4	—	—	58100-58599	105	117
Rochford ...	200	300	—	26	2	3	—	—	56100-56299	92	112
Gt. Wakering ...	100	300	—	—	—	—	2	—	53100-53199	Not yet	ready
Eastwood	Remaining	Manual	at present.						D/O Code 51		
Hockley ...									,, ,, 54		
Shoeburyness									,, ,, 52		
	8,400	17,300	59	624	172	74	2	56		4296	5631

The Auto-manual board is at Southend-on-Sea Exchange. It consists of twenty positions, two of which are equipped for key-sender working.

The old manual exchanges were housed in converted private houses or temporary wooden structures, while the displaced village automatic exchange of 150 lines was contained in a small building designed for a 50-line equipment. All these premises were entirely unsuitable for the accommodation of the new automatic plants and six new buildings were erected. That at Southend, which, in addition to containing the main exchange, houses the Sectional Engineer and his Headquarters Staff, is shown in Fig. 1.

This building is so closely surrounded by other properties that it was necessary to take the

FIG. 1.—SOUTHEND EXCHANGE.

photograph from the top of a near-by pole, hence the obstructed foreground.

A typical satellite exchange of medium size is shown in Fig. **2**, while a smaller one appears in Fig. **3**.

The superseded exchange at Hadleigh, which was opened in February, 1924, was the first automatic exchange to be installed by the Department's Staff. It was also the first village automatic exchange in this country, where individual line switches were dispensed with by the use of line finders. On this system the standard rural automatic exchange has been developed and in view of the present activity in the provision of small units, the picture of the Hadleigh building shown in Fig. **4** will be of interest.

The plant at the six new exchanges was provided and installed by the Standard Telephones

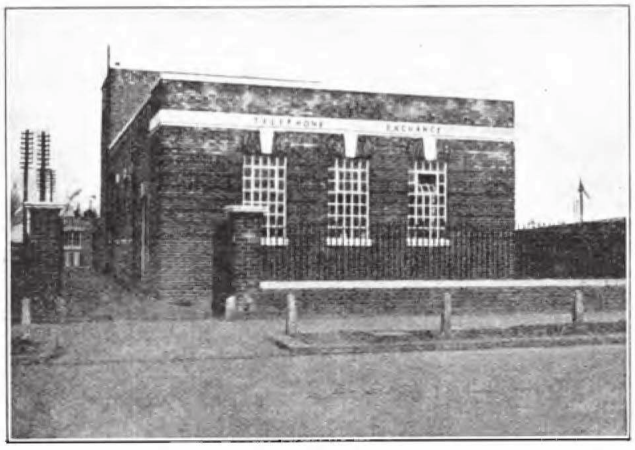


FIG. **2.**—MARINE EXCHANGE.

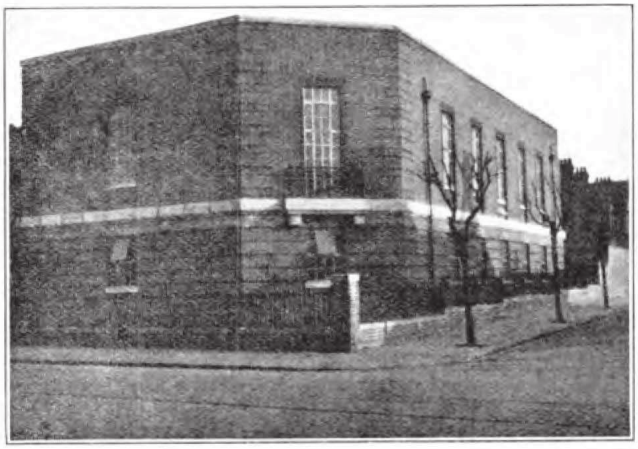


FIG. **3.**—THORPE BAY EXCHANGE.

& Cables, Ltd. The power plant at the three larger exchanges was supplied by the same company, while in the three other cases it was fitted by the Engineering Department's own staff, stock items being used. At Hadleigh and Rochford, there being no public electricity supply, the charging machines are driven by gas engines. In these cases the electric light installations and the ventilating fans are run from the exchange batteries.

At the Southend Exchange a Plenum system of ventilation has been installed. The filter is of the oiled baffle type, the plant being supplied by the Visco Engineering Company.

FIG. **4.**—HADLEIGH VILLAGE AUTO EXCHANGE.

Particulars of the groups of junctions involved are shown in Fig. **5**.

Discriminating Selector Repeaters of the P.O. type were used for the first time at satellite exchanges in the Southend Multi-exchange Area. For local calls they act as group selectors after absorbing one or more digits. The D.S.R's at Hadleigh absorb two digits, while those at Leigh-on-Sea, Marine and Thorpe Bay absorb one digit. For junction calls they function as repeaters.

The D.S.R's call forth comment from visitors on account of their unusual length. This is to enable them to accommodate the discriminating relays on the selector base plate. A near view of one of the new switches appears in Fig. **7**.

The following is an illustration of the functioning of a D.S.R. which absorbs two digits:—

A Hadleigh subscriber calls another Hadleigh subscriber. All Hadleigh numbers have the figures 58 for their first two digits. When the calling subscriber removes his receiver, his line

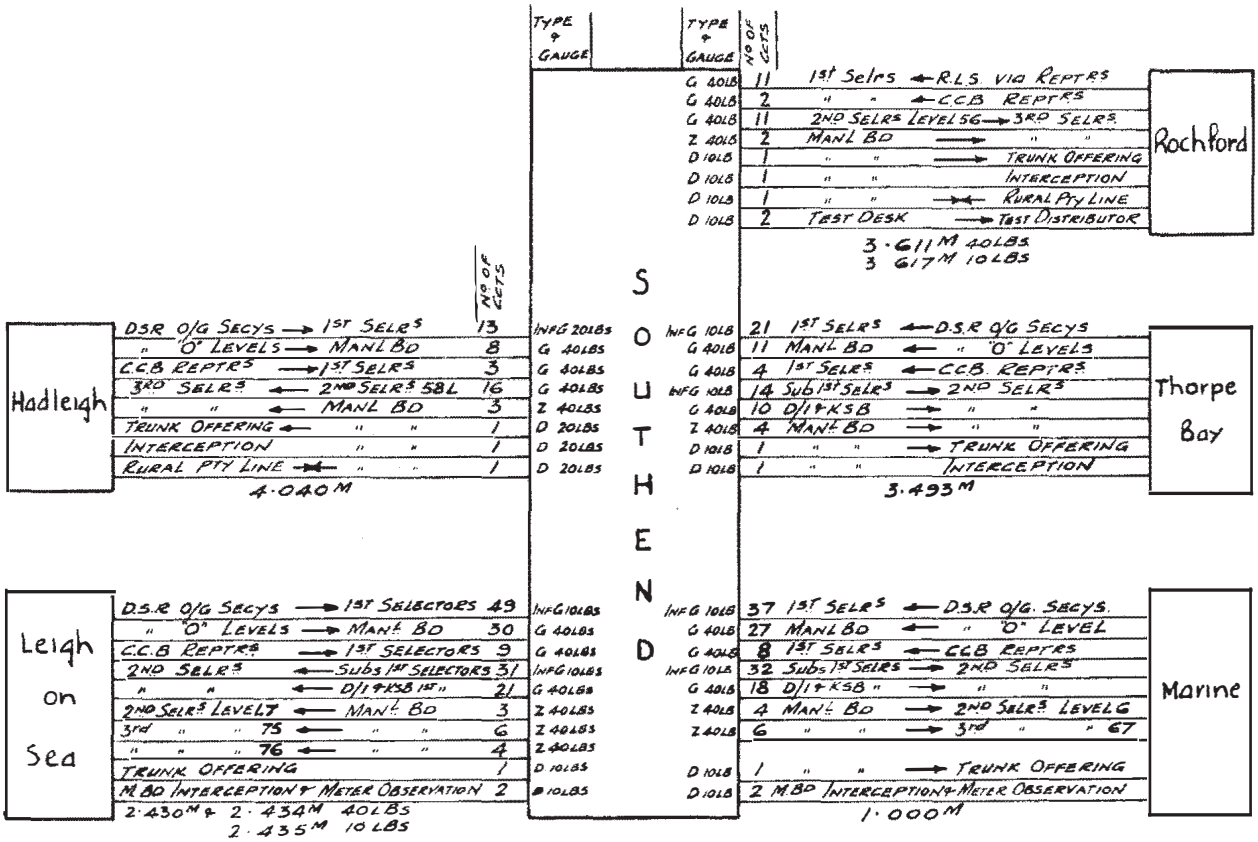


FIG. 5.—JUNCTION GROUPS.

A rack of D.S.R's at Thorpe Bay exchange is shown in Fig. **6**. An outgoing secondary switch of the rotary line switch type is associated with each Discriminating Selector Repeater. These secondary switches, which can be seen mounted in two rows at the top of the rack, find junction outlets for use when a call to another exchange is required.

" O " level calls are not routed in this way, however, but *via* a separate group of junctions connected to the " O " level of the D.S.R. banks.

switch hunts and seizes a D.S.R., the outgoing secondary (O.G.S.) of which seizes a first selector at Southend which gives the calling subscriber " dialling tone." When the first digit " 5 " is dialled, the shaft of the D.S.R. rises to level 5, cuts in and tests the first contact, causing the release to operate and drop out the shaft. Meanwhile the first selector wipers in the main exchange have risen to level 5, cut in and seized a second selector. When the second digit 8 is dialled, the D.S.R. shaft rises to the eighth level, cuts in and is again released. The shaft of the

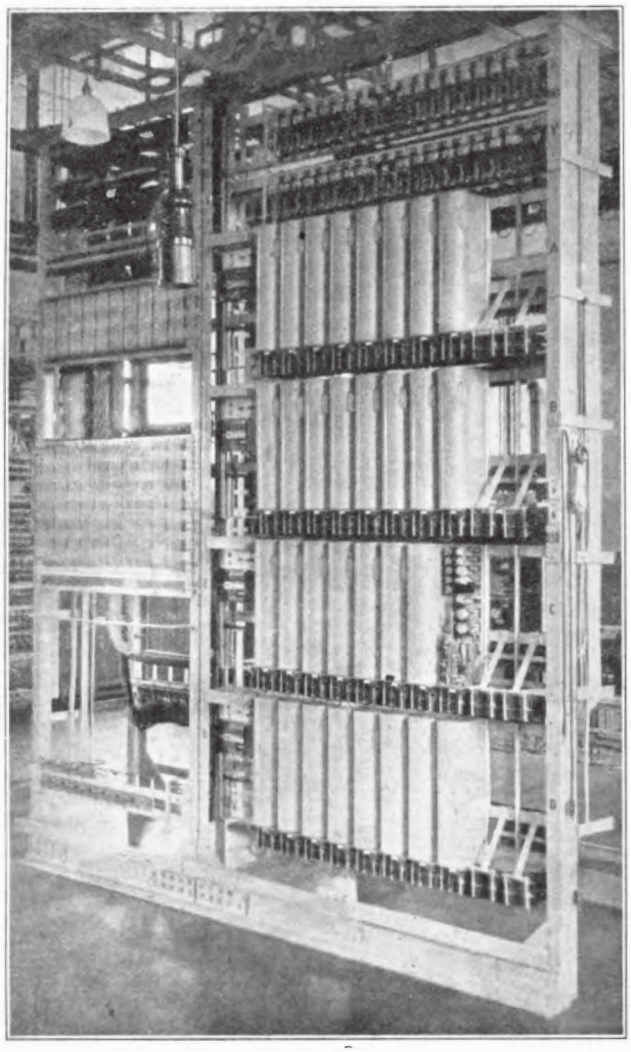


FIG. 6.—RACK OF DISCRIMINATING SELECTOR REPEATER, THORPE BAY.

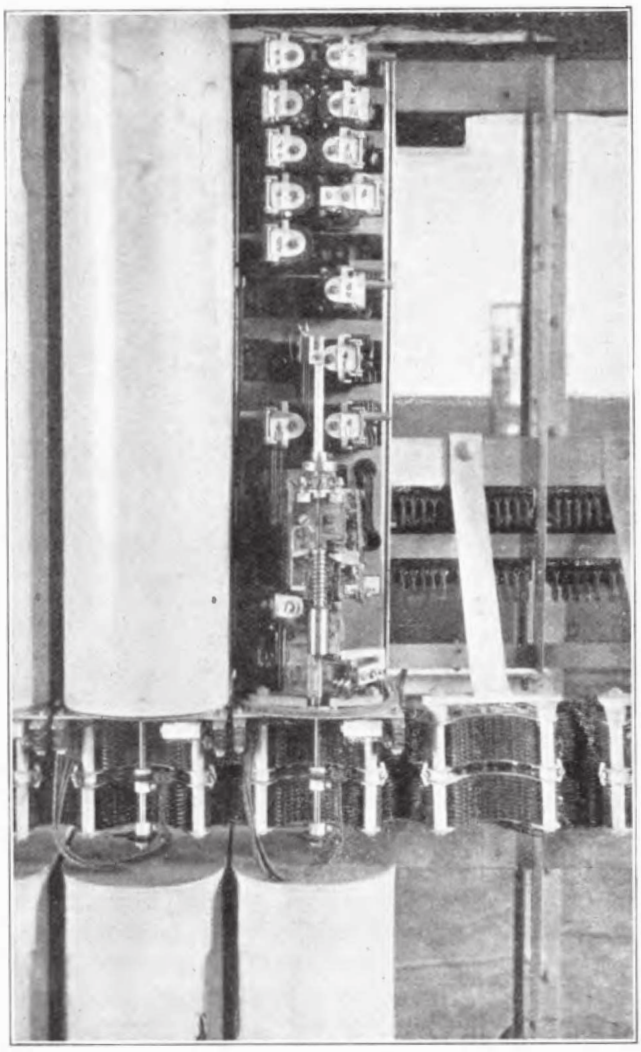


FIG. 7.—D.S.R'S WITH RELAYS.

second selector in the main exchange rises and cuts in momentarily, but the junction is released at once by the D.S.R. at Hadleigh, thus freeing the first and second selectors at the main exchange. When the third digit is dialled, the D.S.R. raises its shaft to the appropriate level and acting as a 3rd selector cuts in and obtains an idle final selector. The two last digits operate the final selector and the call proceeds in the usual manner.

When a Hadleigh subscriber dials " O," the D.S.R. shaft rises to " O " level and, rotating over it, finds an idle outlet to the Manual Board.

When a Hadleigh subscriber dials, as first digit, any figure but 0 or 5 or, having dialled 5 as first digit, uses as second digit a figure other than 8, the D.S.R. shaft rises and remains operated. The call proceeds, *via* the outgoing secondary and junction, to the main exchange where it is dealt with by the selectors and routed according to the number dialled.

Fig. 8 is a diagram of the conditions.

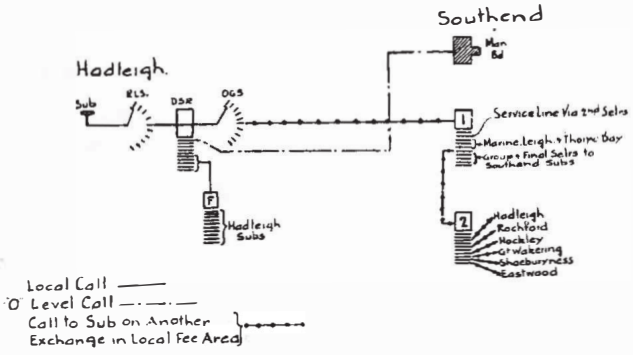


FIG. 8.—HADLEIGH-SOUTHEND CIRCUIT.

At Leigh-on-Sea, Marine and Thorpe Bay Satellite Exchanges, where only one digit is absorbed, the D.S.R's drop out when the first digit dialled is 7, 6 or 8 respectively. The D.S.R's then act as second selectors, third selectors being necessary for five figure local numbers.

In the case of Rochford, the number of local calls being relatively small, the subscribers' Rotary Line Switches seize First Selectors located at Southend. Only Third and Final Selectors are required at Rochford, apart from the subscribers' line equipments, junction repeaters, etc. All calls are routed *via* Southend and in the case of a call from one Rochford subscriber to another, two Southend junctions are used. This "in-and-out" arrangement is known to circuit and switch men as "Trombone" working.

The Key-sending "B" positions at Southend are not of the sloping panel type used in Director areas, but are made to mount "en suite" with the Auto-manual board. In Fig. **9**, it will be seen that the junction lamps and assignment keys are mounted in the space usually occupied by cord circuit keys, while the Dis and Busy keys are in the panels.

A view of the group selectors and special apparatus racks in the main apparatus room at Southend appears in Fig. **10**. The first selectors are on the four boards on the right. They are of the 200 outlet type, hunting over two levels of 10 simultaneously and therefore having 600 point banks.

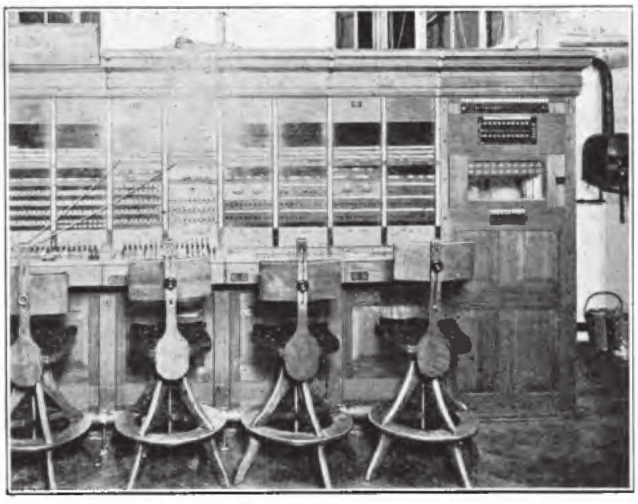


FIG. 9.—SOUTHEND MANUAL ROOM. C.T. SECTION AND METER PANEL. KEY-SENDING B POSITIONS (1 AND 2). COMBINED A AND B POSITIONS (3 AND 4).

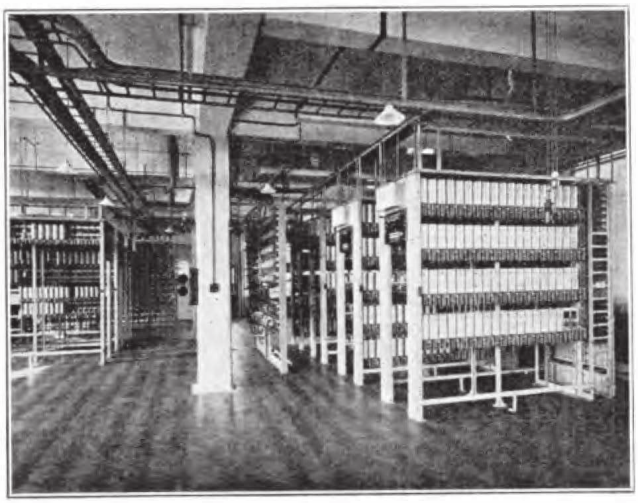


FIG. 10.—GROUP SELECTORS AND SPECIAL APPARATUS RACKS, SOUTHEND.

Figs. **9** and **10** are from photographs kindly supplied by Messrs. Standard Telephones & Cables, Ltd.

The work in connection with the external plant was of considerable magnitude, a very large development scheme having to be carried out simultaneously with the transfer arrangements. To prevent disturbance of circuits after the change-over, it was necessary that the re-distribution covered by this scheme should, as far as it was possible, be completed beforehand. The work which was due for completion by April 27th, 1929, was commenced on June 4th, 1928. Apart from a considerable amount of renewal work, mainly on D.P's and subscribers' terminals, the following is approximately what was achieved in connection with transfer arrangements, junction requirements, new development plant and rearrangements:—

	Main Exchange Area.	Main Exchange Auto.	Junctions. Auto.
Duct Work Completed	9.5 mls.	8.5 mls.	6.5 mls.
Cabling Completed ...	21.6 ,,	17.0 ,,	13.6 ,,
(1) Additional D.P's. and Distribution Points	290 =	216 new D.P's erected 74 existing poles converted.	
(2) Total Number of new D.P's brought into use and existing D.P's rearranged	492		
(3) New wire erected in connection with (2)	59 mls.		
(4) Overhead wire recovered in connection with (2)	540 ,,		

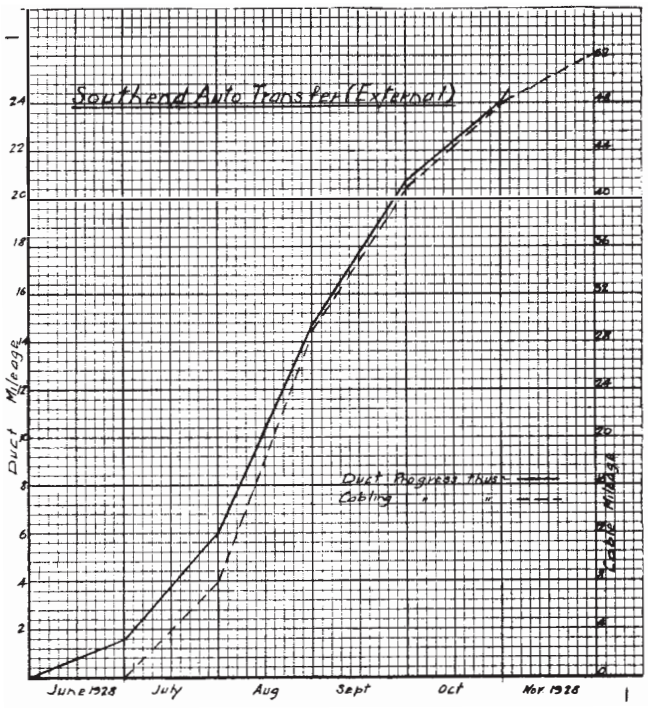


FIG. 11.

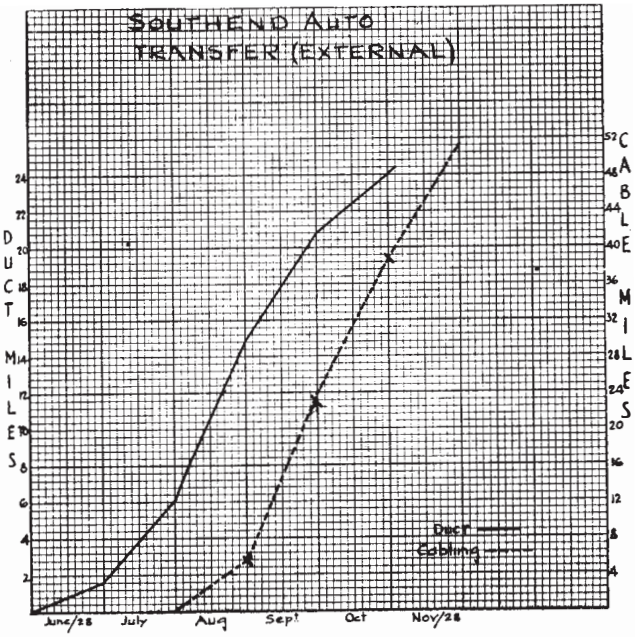


FIG. 12.

Figs. **11** and **12** shows the duct and cabling progress. In connection with the duct work four E.O's were issued (1) for an advance portion covering busy thoroughfares which had to be completed before the commencement of the summer season; (2) Junction scheme; (3) Main Exchange Area; (4) Marine Exchange Area.

A steady progress of approximately 2000 yards per week was maintained on duct work, employing five to seven Contractors' gangs.

Cabling work was carried out at high pressure. At the busiest periods as many as five gangs were employed on rodding and cabling. It will be gathered that the supply of cable was given priority to enable such progress as is indicated by the graph, to be maintained.

In the various areas, Southend, Leigh-on-Sea, Hadleigh, Thorpe Bay, and Rochford, 49 cable jointers were employed. A large proportion of the overhead rearrangement work was put in hand prior to the completion of the underground sections and D.P. branches. Work at D.P's was advanced by running new leads and spurs to subscribers' premises, in readiness, so that on completion of the underground cables, only change-over and recovery work remained to be done on the open lines.

THE ACCURATE MEASUREMENT OF ARTICULATION.

JOHN COLLARD, B.Sc.(Eng)., A.M.I.E.E.

1.0. *Introduction.*

THE value of articulation measured on a given telephone circuit is so obviously a logical measure of the performance of the circuit from the speech point of view, and the carrying out of an articulation test is, at first sight, such an easy operation, that many people must have wondered why articulation does not occupy a more prominent position among the different quantities used in telephone measurements. The reason that it does not do so is that, while the equipment required to carry out an articulation test is comparatively simple, the results depend so essentially on the human element that serious errors are liable to occur unless special precautions are taken in making the test. The results of articulation tests, when carried out carefully under proper conditions, are so valuable, however, that during the last few years a comprehensive study of the whole subject has been undertaken, first by the International Standard Electric Corporation and lately by the International Telephone and Telegraph Laboratories, Incorporated, with a view to determining how an articulation test can most accurately be carried out. This study embraces both the theoretical and practical aspects of the problem, and, since the results are of considerable interest to telephone engineers, it is proposed to give here a brief description of what has been done. Two previous papers* † by the author have dealt in considerable detail with the theoretical side of this work, and it is, therefore, proposed in the present paper to deal chiefly with the practical application of this work to the development of a technique for the accurate measurement of articulation.

* "*A Theoretical Study of the Articulation and Intelligibility of a Telephone Circuit,*" *Electrical Communication, Jan., 1929.*

† "*The Calculation of the Articulation of a Telephone Circuit from the Circuit Constants,*" *Electrical Communication, Jan., 1930.*

2.0. *Articulation and Intelligibility.*

Before going further into this subject, it may be as well to describe the different quantities that have been used in the past as a measure of the articulation of a telephone circuit.

Since the telephone circuit is designed primarily to transmit conversations from one subscriber to another, it appears reasonable, at first sight, to make the articulation test approximate as nearly as possible to an ordinary conversation. With this end in view, a series of sentences are prepared and are called over the circuit to be tested. For the sake of simplicity these sentences are usually arranged so that each conveys a single intelligible idea, such as "The engineers quickly repaired the car." The percentage number of these sentences that are correctly received by the listener is then defined as the intelligibility or sentence articulation of the circuit.

A test of this nature takes a considerable time to carry out and the results are liable to be inaccurate, owing to the fact that they depend so essentially on the number and length of the words used in the test sentences. To overcome these difficulties it is usual to employ a rather simpler form of articulation test in which either separate words or just meaningless syllables are called over the circuit. If actual words are used, ordinary spelling can be used so that the testers do not have to learn a special phonetic script, but there is the disadvantage that errors may occur due to the possibility of the listener being able to guess a word even when he has not heard all the component sounds correctly. When words are used, the percentage number correctly received by the listener is called the word articulation.

To avoid any guesswork on the part of the listener, meaningless syllables are most commonly employed. The disadvantage is that, since the syllables are not actual words, some doubt may arise in the caller's mind as to how they are to be pronounced; and when the listener's form is being corrected, ambiguous spelling may make it difficult to decide whether he correctly received a

syllable. The best way of avoiding this trouble is to adopt a form of special phonetic script in which a given sound is always represented by the same symbol. It has been found that callers and listeners very quickly learn a phonetic script of this nature and that no additional errors are caused by its adoption. Each syllable called over the circuit will, of course, consist of several individual speech sounds; a speech sound being either a consonant or vowel. If the percentage number of syllables correctly received over the circuit is determined, this is called the syllable articulation. If the percentage number of individual speech sounds is determined, this is called the sound articulation.

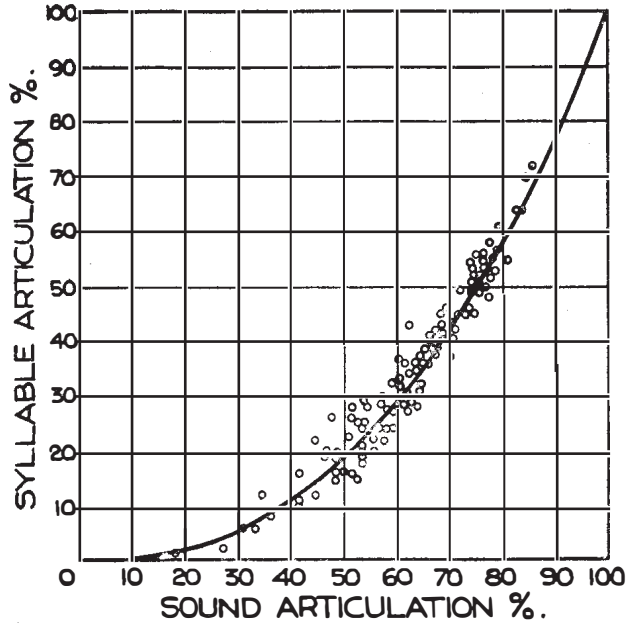


FIG. 1.

3.0. *Theoretical Relationships.*

In one of the papers* referred to above it was shown that, in spite of the fact that the different values of articulation depend essentially on certain characteristics of the testers, and in spite of the fact that word articulation and intelligibility introduce what is apparently guesswork on the part of the listener, there is a perfectly definite theoretical relation between the average values of these different quantities. By making certain reasonable assumptions as to the psychological processes taking place in the mind of the listener and by the use of the ordinary laws of probability, definite algebraic formulæ were established giving the theoretical relationships

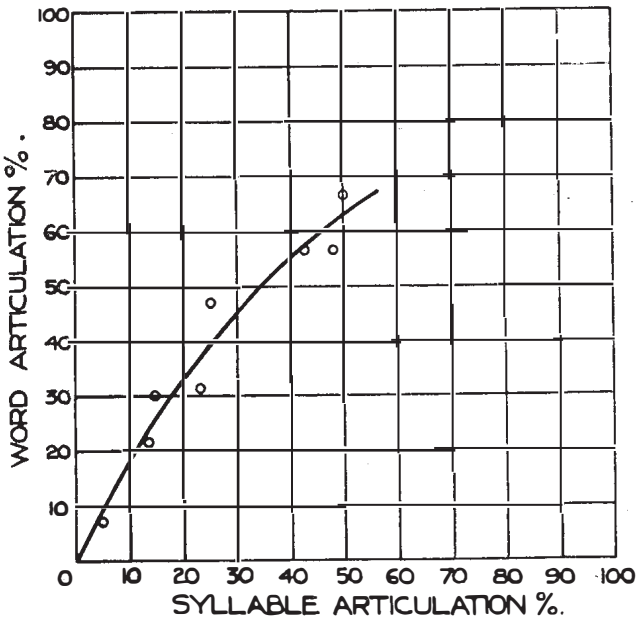


FIG. 2.

between the different quantities. In order to determine whether these theoretical relations agreed with practical results, a number of experiments have been carried out in which the different quantities were measured by means of actual articulation and intelligibility tests. Since the very close agreement between the theoretical and practical values is one of the most interesting results of this work, a number of examples have been given in this present paper. These examples are shown in Figs. **1**, **2**, **3**, and **4**. In

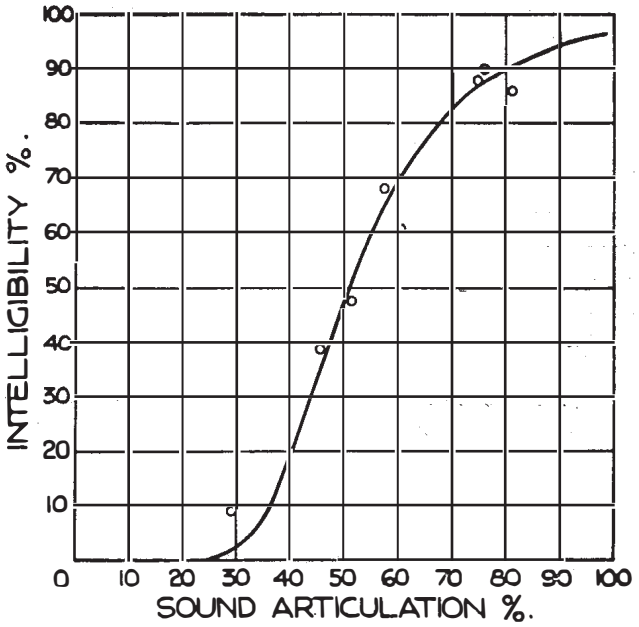


FIG. 3.

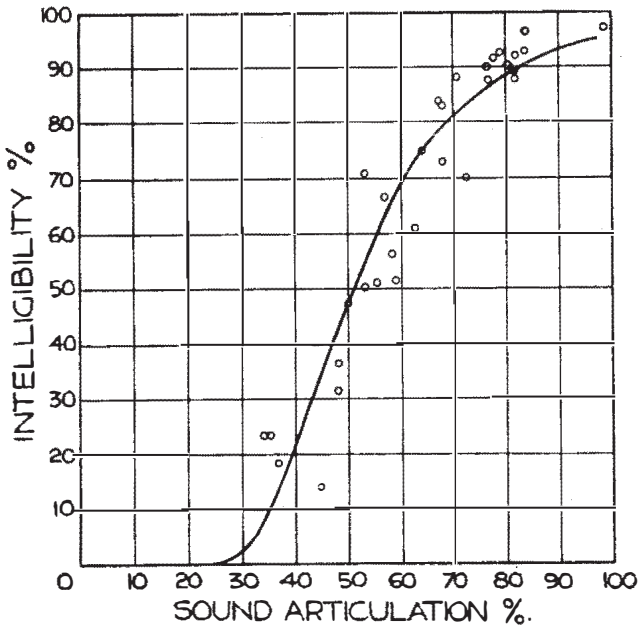


FIG. 4.

each example the curve is calculated from the theoretical formula, while the small circles are the actual measured values. It will be seen that in every case the theoretical curve passes closely through the centre of the experimental points, showing that the agreement between theory and practice is very good.

The formulæ are given below, for the full meaning of the different constants and the methods of evaluating these, reference should be made to the previous paper.*

$$S = 100 \left(\frac{D}{100} \right)^n$$

$$W_n = \frac{100}{1 + k_n \left| \left(\frac{100}{D} \right)^n - 1 \right|}$$

$$I = \frac{100}{1 + h \left| \left(\frac{100}{V} \right)^m - 1 \right|}$$

$$V = \frac{1}{100} \sum p_n W_n$$

where D = average percentage sound articulation.

S = average percentage syllable articulation.

W_n = average percentage word articulation for words of n sounds.

I = average percentage intelligibility.

h, m, p, and k_n are constants depending on the language for which the results are obtained.

In the second paper† referred to above, these theoretical relations were carried a step further and it was shown that, just as intelligibility could be calculated in terms of word articulation and word articulation in terms of sound articulation, sound articulation could itself be expressed as a function of a new quantity called the band articulation. This new quantity was introduced chiefly because it enables the articulation of a telephone circuit to be calculated merely from a knowledge of the constants of the circuit. It is mentioned here, however, because its use has enabled a very simple method of calibrating an articulation crew to be developed. This method has the double advantage of having a sound theoretical basis and of giving satisfactory results in practice. A description of the practical application of the method is given in section 6.0, so that the remarks here are confined to a short discussion of the reasoning on which the theory is based.

It was shown that, while each speech sound contained frequency components throughout most of the audible range, the large components by which the sound is recognised are all grouped together into one or more little frequency bands. The number of these bands in a sound varies from one to five according to the sound. Since it is by noting at what frequency these bands occur that a listener distinguishes one sound from another, they have been called the characteristic band of speech. We can imagine the listener as receiving the different characteristic bands of a sound, considering each one in turn, recognising at what frequency it occurs and so deciding on what sound was called. The probability that the listener will receive a sound correctly is therefore closely related to the probability that he will receive the individual bands correctly. This latter probability is called the band articulation since it is analogous to sound articulation. It will be realised that since each sound consists of one or more characteristic bands, just as each word consists of one or more

sounds, the formula relating sound articulation and band articulation will be of exactly the same form as that relating word articulation and sound articulation.

The expression giving the relation between the average sound articulation and the average band articulation is :—

$$D = \sum \frac{100\, k_l}{1 + c_l \left(\frac{1}{b^l} - 1 \right)}$$

where b = average percentage band articulation.
l = number of characteristic bands in a sound.
and c_l and k_l = constants.

The curve obtained from the above expression is shown in Fig. 5.

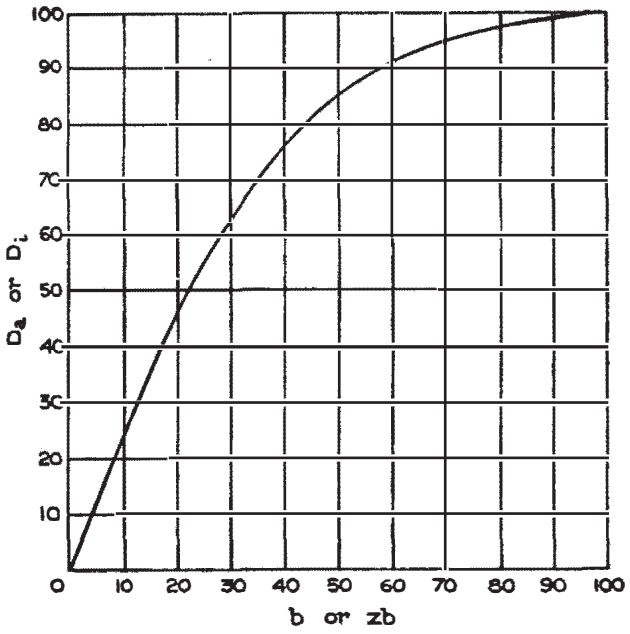


FIG. 5.

4.0. *Choice of a Quantity to be used as a Criterion of Circuit Performance.*

Each of the quantities mentioned above has been used in the past as a measure of the performance of a telephone circuit from the speech point of view. This leads to considerable confusion and it is consequently very desirable that some one quantity should be standardised for future use. Some consideration is therefore given in this section to the relative advantages and disadvantages of the different quantities, from the point of view of their value as a criterion of circuit performance and also from the point of view of their application to practical measurements.

Intelligibility tests have several disadvantages from the practical point of view, the chief among which are the lengths of time required for the test and the difficulty of obtaining accurate results, owing to the large number of factors which may cause random errors. Intelligibility, however, is probably the best criterion of circuit performance, since the telephone circuit is usually required to transmit ideas from one subscriber to another.

Word articulation requires less time for a test than intelligibility and is somewhat less subject to the effect of chance factors. Apart from this, however, it has little to recommend it.

Syllable and sound articulation are both measured by calling syllables over the circuit. The use of test syllables, of course, has the great advantage that it eliminates the guesswork that occurs when words or sentences are used, and requires only a comparatively short time to make the test. These two quantities are, therefore, much to be preferred to the others and it only remains to decide whether syllable or sound articulation should be used. Some difference of opinion exists on this question, but the results of this study have led to the adoption of sound articulation as the most suitable quantity from all points of view. Syllable articulation depends essentially on the number of sounds in the test syllables. A circuit which gave a sound articulation of 70%, for instance, would give a syllable articulation of 49% if 2-sound syllables were used and 34% if 3-sound syllables were used. Where syllable lists are used in which syllables containing different numbers of sounds are included, the result will depend, of course, on the percentage number of each type of syllable. If, therefore, an experimenter states that he has obtained a value of syllable articulation of, say, 50%, on a certain circuit, this statement gives no idea of the performance of that circuit unless he tells us at the same time exactly what type and proportion of syllables he is using. In other words, the standardisation of syllable articulation is really no standardisation at all. Sound articulation, on the other hand, is practically independent of the number of sounds used in the

test syllables, provided syllables of only two or three sounds are used. In consequence, if a value of sound articulation is quoted, it is not important to know what type of test syllables were used. The probable error is less for sound articulation than it is for syllable articulation for most practical cases. This is an important advantage of the use of sound articulation.

When a change of some sort is made in a given telephone circuit, the change in intelligibility is more nearly equal to the change in sound articulation than it is to the change in syllable articulation. This is a further reason for preferring sound articulation to syllable articulation.

For these reasons, and as a result of several years of practical testing of articulation, it has been decided to standardise sound articulation as a measure of the performance, from the speech point of view, of telephone circuits and apparatus.

When an articulation crew is used to measure articulation on a given telephone circuit, the value they obtain will depend, to a certain extent, on the amount of previous training they have had. The value obtained will also depend on the mental development of the members of the crew. For this reason, it is very difficult, if not quite impossible, to compare articulation results taken by different crews or even results taken by the same crew at different periods. To overcome this difficulty it is proposed to use a quantity called the Ideal Sound Articulation. This quantity is defined as the value of articulation that would be obtained on a given circuit by an ideal crew. It is obviously independent of crew factors and depends solely on the circuit. In the section dealing with the calibration of a crew it will be shown that it is possible to calculate the ideal sound articulation from a given measured value.

Out of all these quantities the only one that seems to satisfy all the required conditions is the Ideal Sound Articulation and, since it is proposed to standardise this quantity for all articulation work, a summary of its advantages is given below.

(1) It is independent of the articulation crew used to obtain it.
(2) It is of all the possible quantities the one least affected by the construction of the test lists.
(3) It has the smallest average error for practical circuits.
(4) The change in it, brought about by some change in the circuit, is most nearly equal to the corresponding change in intelligibility.
(5) It is the quantity from which the others can most easily be calculated.

5.0. *Chance Factors.*

The next step in the development of an accurate technique is a study of all the different factors which can influence the value of sound articulation measured on a given circuit. Below is given a list of the most important of these factors, together with a discussion of their effect on articulation and how it can be either eliminated or controlled.

(1) The pronunciation of the caller and any other peculiarity in his speech.
(2) The degree of hearing of the listener.
(3) The mental development of the testers.
(4) The fatigue of the testers.
(5) External conditions, such as room noise.
(6) The degree of training in articulation testing of the testers.
(7) The number of sounds used to form the test syllables.
(8) The frequency of occurrence of the individual speech sounds in the test syllables.

Factors (1), (2) and (3) have a very considerable effect on the value of articulation measured on a given circuit, but their effect can, of course, be controlled to a certain extent by suitably choosing the testers. It is obviously desirable to avoid including anyone with some abnormal pronunciation, some defect in the speech organs or some defect in hearing. Some callers give very variable results due to their not being able to keep their calling volume constant. Other callers fail, due either to over-emphasis of the test syllables or to the adoption of a monotonous tone of voice when calling. These defects can be discovered by simple speech and audiometric tests. It is necessary, of course, in selecting a crew to avoid carrying this elimination of abnormalities too far. Ordinary subscribers vary considerably both in their calling volume and in the degree of hearing, and, consequently, if the results of an articulation test are to be really

representative of actual conditions, a normal amount of variation from one tester to another is to be desired. Also, women as well as men should be included in the crew if really representative results are to be obtained. The mental development of the crew is less easy to determine, but it exerts, nevertheless, an important effect on the results obtained. Some testers, for example, seem quite unable to concentrate upon an articulation test and are useless for the work. Others, while giving good results for the first few tests, soon tire and become quite useless. These defects are difficult to detect by any preliminary tests and probably the only way of avoiding them is to select the testers from a reasonably intelligent class and then to reject, subsequently, any that prove unsatisfactory in this respect.

Factors (4) and (5) are very closely allied, since the external conditions such as the existence of room noise, bad lighting, and uncomfortable seats, very quickly bring about a state of fatigue. A striking example of this is shown in Fig. **6**. A series of articulation tests was being carried out and these tests extended over a period of several weeks. Tests were being made on a number of different circuit conditions and each day a control test was carried out on a standard calibration circuit. Sometimes this control test was made early in the day and sometimes towards the end of the day. The listeners were enclosed in silence cabinets, but these cabinets were far from perfect and, as there was a considerable amount of room noise outside the cabinets, the listeners were subjected to a certain amount of noise which was very tiring. In Fig. **6** the values of articula-

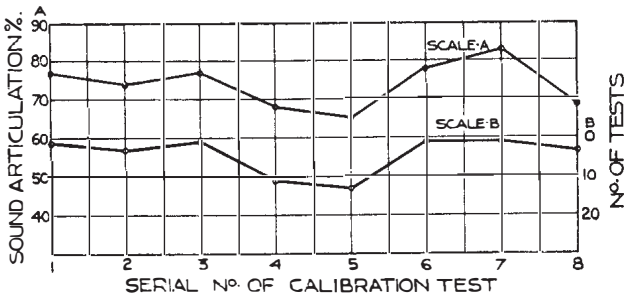


Fig. 6.

tion obtained on the calibration circuit on the different days are plotted in the upper curve and in the lower curve are shown the number of tests which had been carried out each day before the control test was made. It will be seen that there is quite a close agreement between the two curves, the value of articulation obtained in the control test being very much less when it was carried out at the end of the day than when it was carried out at the beginning of the day when the testers were fresh. This shows very clearly that every effort should be made to eliminate as far as is possible the effect of external conditions on the testers. With this end in view, proper silence cabinets should be employed to avoid the effect of external sounds and, where possible, it is desirable to use separate cabinets for each listener so as to avoid one listener disturbing another. Careful attention to the lighting and ventilation conditions is necessary and the seating accommodation should be arranged so that the testers do not have to sit in an uncomfortable position. These points may appear unimportant, but it is only by paying attention to small details of this nature that reliable and consistent articulation results can be obtained.

As an articulation crew becomes trained to a certain technique, the value of articulation that they obtain on a given circuit gradually increases. This effect is shown in Figs. **7** and **8** where re-

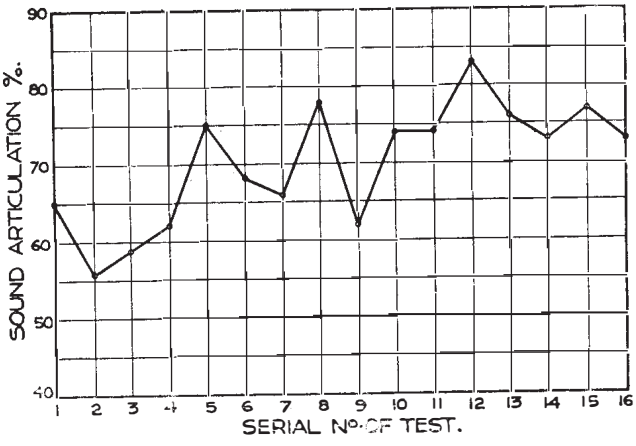


Fig. 7.

sults are given for two different cases. Fig. **7** gives the results for a single caller-listener combination, while Fig. **8** is for the average of two such combinations. It will be seen that the average value of articulation varies from about 60% at the beginning to about 70% at the end of the series of tests. The period of time over which this gradual improvement occurs varies for different testers. In some cases it has been

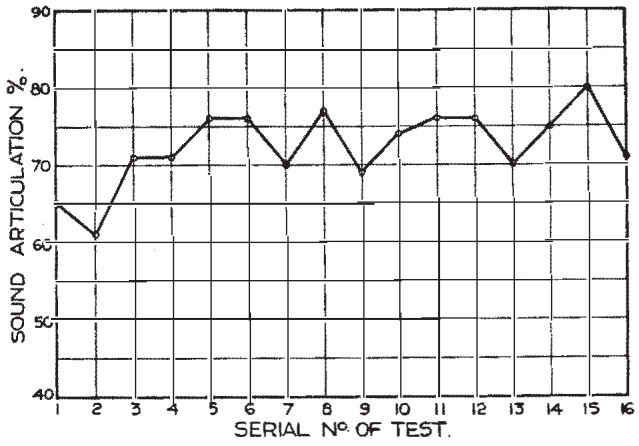


FIG. 8.

found that a tester reaches his steady state value in about a week, while in other cases the average curve still rises after two or three months. Even when two articulation crews are fully trained and have reached their steady state value, they will not necessarily obtain the same value of articulation for a given circuit, even if the average of a number of tests is taken. This is due, of course, to inherent differences in the testers composing the two crews. Measured values of articulation are, therefore, only relative and not absolute. To overcome this trouble and to avoid as far as is possible errors due to the fatigue and training effects, a method of calibrating an articulation crew has been devised. This method is discussed fully in the next section.

The number of sounds used in the test syllables and the frequency of occurrence of the individual sounds will both affect the articulation obtained, and their choice depends on whether or not the results are to approximate as closely as possible to speech conditions. There appears to be some difference of opinion on this point. Some writers have advocated a technique in which both the frequency of occurrence of the individual sounds and the arrangement of the test syllables approximated very closely to speech conditions, in order that the results shall represent a true criterion of speech. Other writers have argued that for practical testing it is better to simplify the technique as far as possible by using only one type of syllable and a uniform frequency of occurrence for the individual sounds. In the technique which was developed as a result of this study, lists are used in which the advantage of simplicity and a close approximation to speech conditions are combined. These lists consist each of 200 sounds formed into 80 syllables, of which 40 are of the form consonant-vowel or vowel-consonant while 40 are of the form consonant-vowel-consonant. The frequency of occurrence of the individual sounds is arranged to be the same as in ordinary English speech. In making the analysis from which these frequencies of occurrence were obtained, only the key words in the sentences were analysed and actual spoken English was used. A key word in a sentence is defined as any word which carries an appreciable proportion of the sense of the sentence, so that its omission from the sentence would make the meaning obscure or ambiguous. The syllables are formed from the sounds entirely at random.

It will be obvious that these syllable lists are simple in form; the only further simplification that could have been made would be the use of only one type of syllable instead of two types. It was thought, however, that the very slight sacrifice in simplicity due to the use of two types of syllable was more than offset by the better approximation to speech conditions. It only remains to show, therefore, that these lists do approximate very closely to speech conditions and that further complications in the types of syllable employed are not actually necessary. In the course of this work it has been found that double consonants of the type pl, st, br, nt, etc., are received by the listener almost as though they were single sounds, so that syllables of the form consonant-consonant-vowel-consonant give the same articulation as syllables of the form consonant-vowel-consonant and syllables of the form vowel-consonant-consonant give the same articulation as syllables of the form vowel-consonant. It is therefore possible in an articulation test list to substitute more simple syllables for the more complicated forms without affecting the value of articulation obtained. If this is done it is found that approximately half the syllables employed in ordinary speech can be represented by the form consonant-vowel-consonant and half by the form vowel-consonant or consonant-vowel. It is of interest to note that Fletcher in a recent publication‡ arrives at the same result. As a final demonstration of the accuracy with which syllable lists of the form described here approxi-

mate to actual speech conditions, the results of Figs. **2**, **3** and **4** can be used. The theoretical value of word articulation and intelligibility in these figures was calculated using values of sound articulation obtained with the syllable lists just described. Since the calculated results do agree very closely with the measured values of word articulation and intelligibility, and since actual speech tests were used to obtain the measured results, it follows that these syllable lists do give results which are a good criterion of actual speech. Tests made with lists including more complicated syllable forms gave results which, as might be expected, varied more widely about the mean than do results obtained with the simpler forms. It is therefore desirable to omit all complicated forms from the syllable lists. On the whole, therefore, it seems reasonable to assume that the syllable lists suggested here form a satisfactory practical compromise between extreme simplicity and an absolute imitation of speech forms. The lists described here have, of course, been arranged for the English language, but similar arguments apply to any other language.

6.0. *Calibration of Articulation Crew.*

From the previous section it will be obvious that, while the effect of some factors on articulation results can be eliminated or reduced within permissible limits, there are certain quite important factors which cannot be removed. Examples of the latter are the effects of training and fatigue. While factors of this nature still exist it is obviously very difficult, if not quite impossible, to compare results taken at one time with results taken at some other time, or to compare results taken by different crews. To overcome this difficulty, a method has been developed by means of which it is possible to calibrate an articulation crew.

In a previous section it was shown that sound articulation could be expressed as a function of the band articulation. When a sound is transmitted to the listener, there are two factors which determine whether or not he will recognise a given characteristic band. The first of these factors depends on the characteristics of the circuit over which the sound has been transmitted; if the circuit introduces a large amount of distortion, the listener will find it difficult to recognise the characteristic band. The second of these factors depends on the characteristics of the listener; if he thinks slowly or if he is unable to keep his attention from wandering, he will find it difficult to recognise a characteristic band. It is this second factor which changes as the listener becomes properly trained or as he becomes fatigued. Suppose that we take an ideal listener, *i.e.*, one for whom the second factor is unity, and determine the average probability that he will receive a characteristic band correctly over a given circuit, let this probability be b. Now suppose we take a given listener who is not ideal and determine the probability that he will receive a characteristic band correctly over an ideal circuit, *i.e.*, a circuit for which the first factor is unity, let this probability be z. Then, if we use the given listener on the given circuit, the probability that he will receive a characteristic band correctly will be the product of the previous two probabilities, in other words it will be equal to zb. This assumes, of course, that the value of z really is a constant for the listener and is not affected by the kind of circuit on which he measures. The extent to which this assumption holds good in practice will be discussed later, for the moment it will be assumed that it does so.

In the second paper† referred to above it was shown how b could be calculated for a circuit. If, therefore, we take a circuit for which we know b and measure a value of sound articulation on it with a crew whose calibration is to be determined, then from Fig. **5** we can find the corresponding value of zb and knowing b we thus determine z for the crew in question.

Suppose now that it is required to determine the ideal sound articulation for a given telephone circuit using the crew which has just been calibrated. We obtain a value of sound articulation with this crew on the given circuit and from Fig. **5** determine the corresponding value of zb. Since we know z for the crew, we can immediately calculate b and then from Fig. **5** again we can find the value of sound articulation corresponding to b. This value will be the ideal sound articulation, since it is the value corresponding to zb when z is unity.

‡ "*Articulation Testing Methods.*" *H. Fletcher and J. C. Steinberg. Bell System Technical Journal, October, 1929.*

The success of this method of calibration depends on the correctness of the assumption that z is a true constant for a given crew and does not vary according to the circuit conditions under which it is measured. It does not seem immediately obvious from any theoretical reasoning that this should be so. Indeed, one might be justified on theoretical grounds in assuming that when a listener is using a bad circuit he exerts a greater effort and, since z is a measure of his mental effort, we might expect z to change. As a matter of fact when the author first attempted to calculate intelligibility from sound articulation exactly the same objection was raised; it being

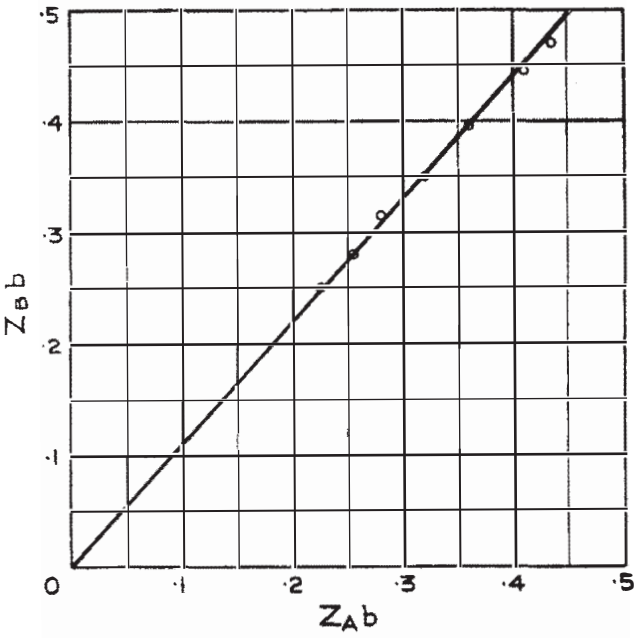


FIG. 9.

said that the practical results would never agree with the theoretical results because, when the listener was using a bad circuit, there was a variable factor depending on the amount of effort exerted by him. Actually, as will be seen from the curves given in this paper, the practical results do agree with the theoretical results, so that, apparently, this variable factor does not exist. In exactly the same way it has been found that z really is a constant for a given crew. This will be obvious from Figs. **9**, **10**, **11** and **12**. Fig. **9** was obtained in the following way. A series of articulation results were measured on a circuit whose attenuation could be varied. Results were

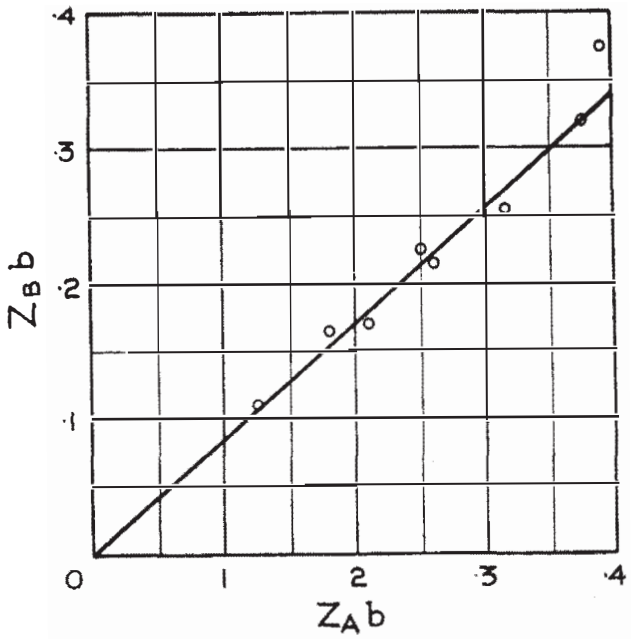


FIG. 10.

obtained for different values of attenuation and for each value of attenuation two values of articulation were obtained, one with a crew A and one with another crew B. Corresponding values of sound articulation D_A and D_B were converted to values of zb using Fig. 5. A series of pairs of values $z_A b_1$, $z_B b_1$, $z_A b_2$, $z_B b_2$, etc., were thus obtained. If we now divide one value of a pair by the other we get a ratio z_A/z_B and, if z_A and z_B

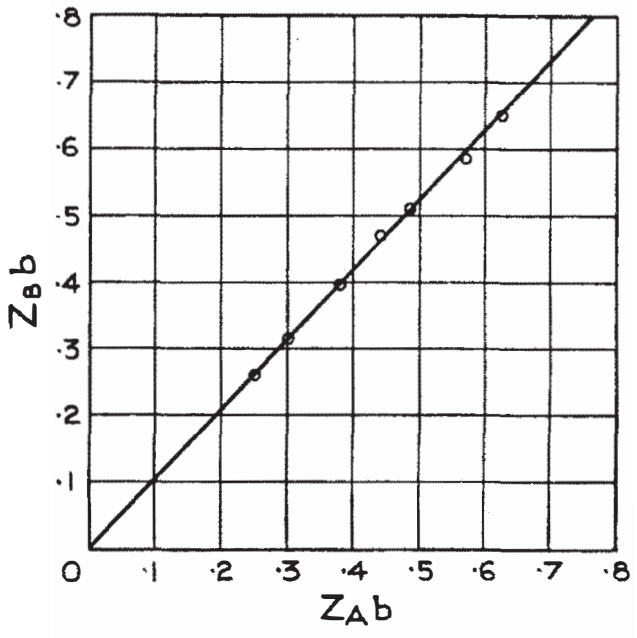


FIG. 11.

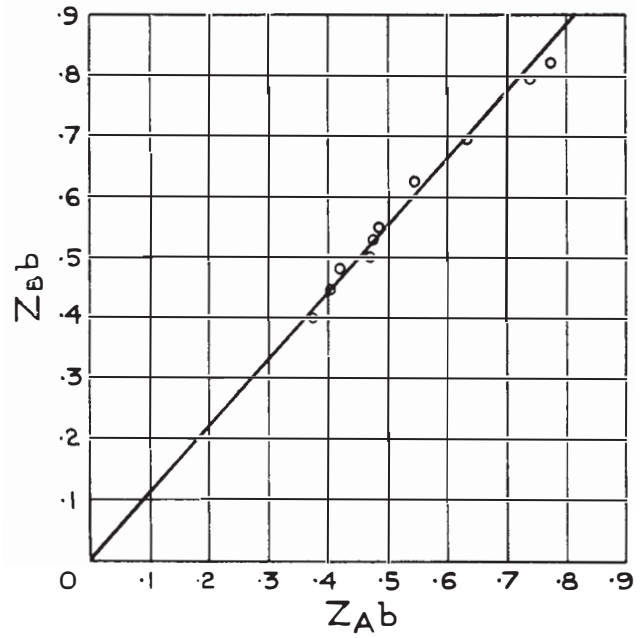


FIG. 12.

really are independent of the circuit condition this ratio should be constant. In Fig. **9** corresponding values of $z_A b$ and $z_B b$ have been plotted one against the other so that, if z_A/z_B is constant, all the points should lie on a straight line through the origin. Fig. **10** was obtained in a similar way except that the circuit condition which was changed was the amount of line noise in the circuit. It will be seen that the points do fall close to a straight line in each case and that this line does pass through the origin. The points do not fall so close to the line in the second case because the testing crew was smaller and the average error was consequently larger. For the first case the average error of the measurements was less than ± 1% and for the second case about ± 2%. In order to give a more general demonstration of the accuracy with this calibration method two further sets of results are given in Figs. **11** and **12**. The points for these two cases were obtained in exactly the same way as for Figs. **9** and **10** except that the values were obtained from some articulation results published recently by Fletcher.‡ It will be noticed that here again the points all lie very close to a straight line through the origin. It is clear from these examples that the assumption of a constant z for a given crew is correct in practice within the limits of experimental error.

It will be as well here to point out under what conditions this method, or indeed any other method of calibration, cannot be expected to give good results. When an articulation crew first starts testing, the values they obtain are low, but gradually increase as the crew becomes more expert. This has been referred to before and is illustrated in Figs. **7** and **8**. If, after the crew has reached a steady state on a certain type of circuit, they are transferred to a different type of circuit, they go through the same process of improvement on the new circuit. This is in spite of the fact that they may be considered fully trained as regards the first type of circuit. The second time, however, the period of training is very much shorter, and the greater and more varied the experience of the crew, the more rapidly do they reach a steady state on a new circuit. If, now, a crew has reached a steady state on the calibrating circuit and is used to obtain results on some new circuit, the values they obtain on the calibrating circuit will be no indication of what variations they may get on the new circuit until after the first few tests on the new circuit have been completed and the steady state on this circuit has been reached. Since, however, the first few tests on a new circuit are never very reliable, they should not be used in any case, so that this does not constitute a disadvantage of the proposed method of calibration.

As an example of the use of this method of calibration, the following case is given. A set of tests was made on four different occasions on a circuit into which a large amount of line noise was introduced. During each of the four tests a calibration reference test was made on a circuit for which the value of b was known. The values obtained are given below together with the corresponding values of ideal sound articulation calculated by means of the calibration method given above.

Measured Sound Articulation. Calibration Circuit.	Test Circuit.	Ideal Sound Articulation.
71.0	51.5	61.5
75.0	58.0	63.5
73.0	51.5	60.0
73.0	53.0	61.5

The average error in the measured values of articulation for the test circuit is ± 4.5% and for

the values of ideal sound articulation ± 1.4%. The average error for the ideal sound articulation is within the limits of experimental error for the individual measurements which in this case were ± 2%.

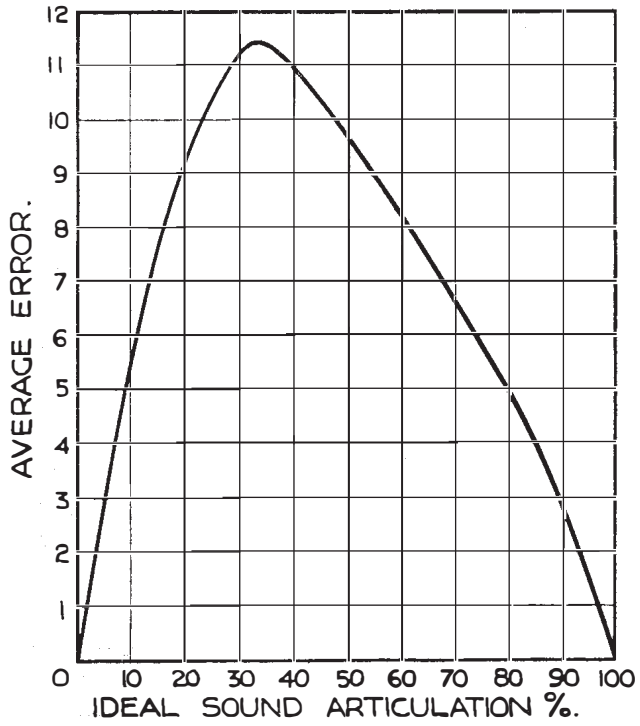


FIG. **13**.

7.0. *Accuracy obtainable in Articulation Tests.*

It is of interest to consider what degree of accuracy can be obtained in an articulation test when all the precautions suggested in this paper are taken, and when the method of calibration described here has been used. The accuracy of the measurements will depend, of course, on the value of articulation, but for a circuit giving an ideal sound articulation of 70—80% such as would be obtained for the average circuit between two subscribers, the average error for a caller-listener combination has been found to be about ± 6%. In this work a crew of nine testers is used, each tester calling in turn to the remaining eight. The average of these 72 results is known as the crew average and the average error for this will be about ± 0.7%.

The average error for other values of articulation is given in Fig. **13**.

8.0. *Conclusions.*

Everyone will doubtless agree as to the desirability of adopting a standardised technique for articulation testing, so that results obtained by different experimenters may be directly comparable. Unfortunately, there is no such uniformity of opinion on the question as to what particular technique should be adopted as standard. However, the technique suggested here includes the advantages of simplicity and a reasonably close approximation to actual speech conditions. In addition it is founded on a sound theoretical basis and confirmed by a long series of practical tests. In particular the novel method of calibrating the articulation crew combined with the use of Ideal Sound Articulation removes one of the chief objections to articulation testing, that is to say, that results obtained at different times or by different crews are not comparable. The accuracy obtainable is such that the average error does not exceed ± 1.5% for the worst case and for normal circuits is less than ± 1%. It is hoped, therefore, that the particulars given here of the new articulation technique may prove of material assistance to all those telephone engineers who have articulation tests to carry out and that it may eventually lead to the adoption of a universal standard technique for articulation testing.

In conclusion, the author would like to thank the International Standard Electric Corporation and the International Telephone and Telegraph Laboratories, Incorporated, for permission to publish the results given in this paper.

AN IMPROVED FORM OF MAXWELL D.C. INDUCTANCE BRIDGE AND A METHOD OF MEASURING THE TIME CONSTANT OF THE CORE OF A MAGNET.

L. H. HARRIS, M.Sc., and H. WILLIAMS, A.C.G.I.

IN the following paper in which various types of D.C. Inductance Bridge are considered the term " current balance " refers to the case where zero deflection of the galvo results from the current in it being zero at every instant, while the term " quantity balance " refers to the case where zero deflection of the galvo results from the aggregate quantity of current through it being zero.

In that form of Maxwell Bridge, shown in Fig. 1, the conditions of balance under A.C. conditions are obtained by equating the products of the impedances of opposite arms of the bridge, that is,

$$QS = (R + j\omega L)\left(\frac{P}{1 + j\omega CP}\right)$$

which, on separating the real and imaginary parts, gives for balance

$$\frac{L}{C} = QS = PR.$$

The conditions are independent of frequency and it follows that they hold for a source containing any combination of frequencies such as the make or break of a battery or any irregular wave shape.

The Rimington-Maxwell Bridge, shown in Fig. 2, is also commonly used for D.C. Inductance measurements, the conditions of balance evolved from equating the products of opposite arms of the bridge being as follows:—

$$QS = (R + j\omega L)\left(P - T + \frac{T}{1 + j\omega CT}\right)$$

$$\therefore QS + j\omega CTQS = (R + j\omega L)(P + j\omega CPT - j\omega CT^2).$$

Separating real and imaginary terms

$$\left.\begin{aligned} QS &= PR - \omega^2 LCT(P - T) \\ CQST &= RCPT - RCT^2 + PL. \end{aligned}\right\}$$

Substituting the essential initial condition for steady balance of PR = QS, two conditions are obtained for balance

$$\frac{L}{C} = \frac{RT^2}{P}$$

and $\omega^2 LCT(P - T) = 0$,

that is, either T must equal P (giving the simple Maxwell Bridge) or else $\omega = 0$, indicating that current balance would only be obtained with very slow sine wave alternations.

It follows from this that if current balance were essential for the balance of this bridge on make or break of the battery, that it could not be used for the measurement of D.C. inductance. Rimington has pointed out, however, that zero deflection of the galvo can be obtained if the conditions are such that the aggregate quantity of electricity through the galvo is zero, in which case current balance can be dispensed with. Mathematical consideration of the simple case where the resistance of the galvo is large follows. Taking first the current balance of the Maxwell Bridge: Consider the " make " of the battery current. The growth of current in P from o to $\frac{E}{P+Q}$ is given by $\frac{E}{P+Q}\left(1 - \epsilon^{-\frac{t}{Cr}}\right)$ where r is $\frac{PQ}{P+Q}$, while the growth of current in S is given by $\frac{E}{R+S}\left(1 - \epsilon^{-\left(\frac{R+S}{L}\right)t}\right)$

The voltages across P and S are therefore $\frac{EP}{P+Q}\left(1 - \epsilon^{-\frac{t}{Cr}}\right)$ and $\frac{ES}{R+S}\left(1 - \epsilon^{-\left(\frac{R+S}{L}\right)t}\right)$ and these must be equal at every instant for current balance. For this to be true, the initial and final voltages must be equal and also the time constants must be equal.

That is, $\frac{P}{P+Q} = \frac{S}{R+S}$, or $PR = QS$.

and $\frac{R+S}{L} = \frac{P+Q}{CPQ}$ *i.e.*, $\frac{L}{C} = \frac{PQ(R+S)}{P+Q} = SQ$.

FIG. 1 MAXWELL

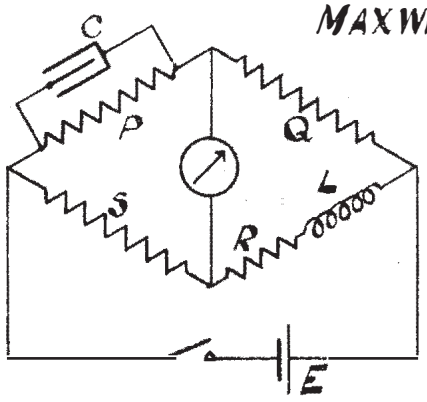


FIG. 2 RIMINGTON—MAXWELL

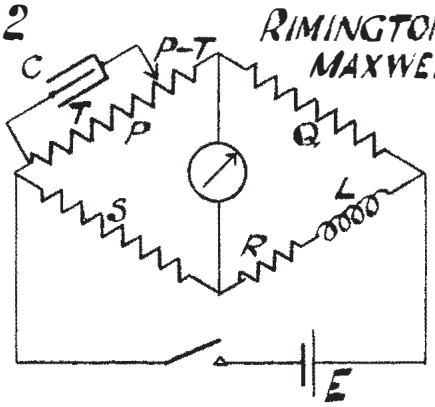


FIG. 3

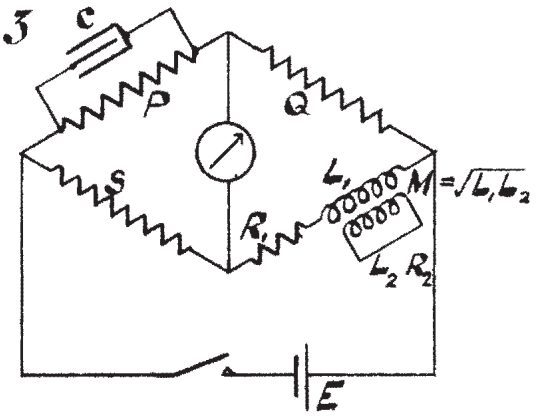


FIG. 4

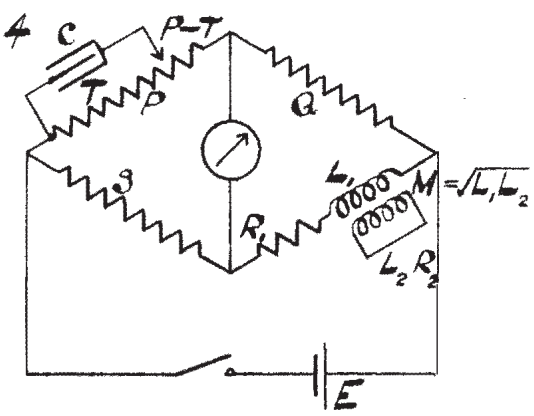


FIG. 5

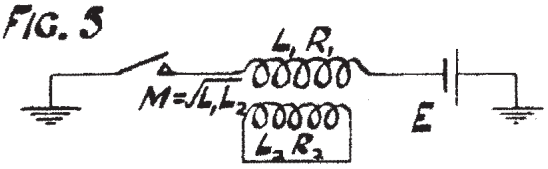


FIG. 6

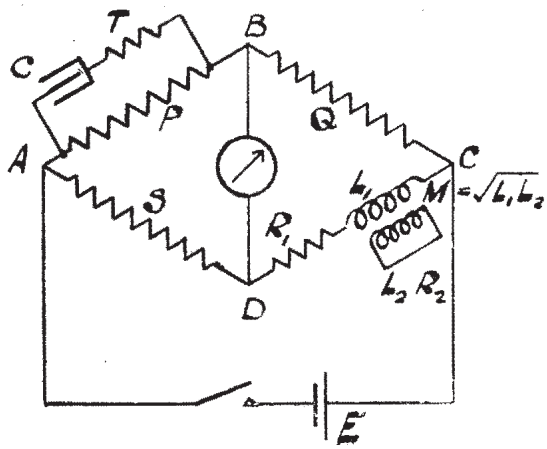
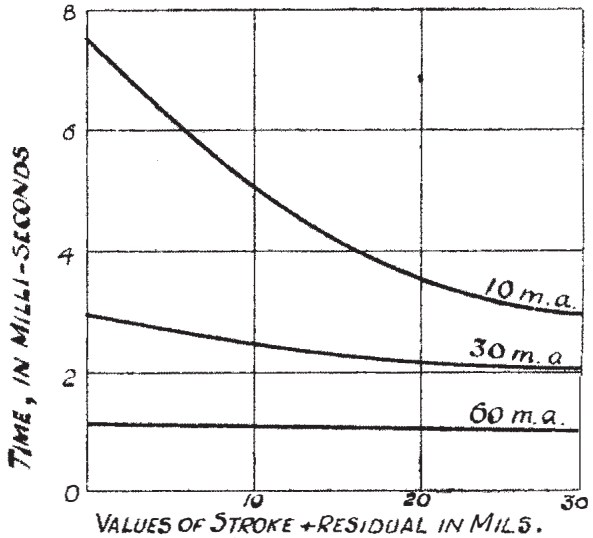


FIG. 7



TIME-CONSTANTS OF RELAY CORE.

These conditions are those obtained in the first instance for the general case.

In the case of the Rimington-Maxwell Bridge (Fig. **2**), the current in the arm Q, on switching on the battery decays logarithmically from $\frac{E}{P+Q-T}$ to $\frac{E}{P+Q}$ according to the law

$$i_Q = \frac{E}{P+Q} + \left(\frac{E}{P+Q-T} - \frac{E}{P+Q}\right)\epsilon^{-\frac{t}{Cr}}$$

where $r = \frac{T(P+Q-T)}{P+Q}$

while in the arms S and R the current grows from zero to $\frac{E}{R+S}$ according to the law

$$i_s = \frac{E}{R+S}\left(1-\epsilon^{-\left(\frac{R+S}{L}\right)t}\right)$$

as in the simple Maxwell Bridge.

It is obvious from the nature of these currents, one jumping immediately to a finite value, and the other growing logarithmically from zero, that the voltage across the galvanometer cannot be zero at every instant and therefore a current balance is impossible. If the voltage across the galvanometer is found and the conditions for making the integral of this voltage zero are calculated, this condition will also be the condition for zero aggregate quantity of electricity in the galvanometer.

From the above, the voltage across Q will be

$$\frac{EQ}{P+Q} + \frac{ETQ}{(P+Q)(P+Q-T)}\epsilon^{-\frac{t}{Cr}}$$

and across R is $E - \frac{ES}{R+S}\left(1-\epsilon^{-\left(\frac{R+S}{L}\right)t}\right)$

$$= \frac{ER}{R+S} + \frac{ES}{R+S}\epsilon^{-\frac{R+S}{L}t}$$

The difference between these voltages gives the P.D. across the galvanometer, and since $\frac{Q}{P+Q} = \frac{R}{R+S}$, this will be:

$$\text{P.D. across galvo.} = \frac{ETQ}{(P+Q)(P+Q-T)}\epsilon^{-\frac{t}{Cr}} - \frac{ES}{R+S}\epsilon^{-\left(\frac{R+S}{L}\right)t}$$

Integrating this expression between the limits $t = 0$ to $t = \infty$ gives

$$-\frac{ET^2QC}{(P+Q)^2} + \frac{ESL}{(R+S)^2}$$

$$= \frac{EQ^2}{(P+Q)^2}\left(-\frac{T^2C}{Q} + \frac{LS}{R^2}\right), \text{ which is zero}$$

if $\frac{L}{C} = \frac{T^2R^2}{SQ} = \frac{T^2R}{P}$ since $PR = QS$.

It will be seen, therefore, with this type of bridge that, although current balance is impossible, a quantity balance may be obtained. It is usual to use a long period galvo for these measurements, but, nevertheless, a double kick is usually visible, which detracts from the accuracy of the result.

The Effect of the presence of a Closed Secondary Winding.

In most inductances in practice, there is present some semblance of a closed secondary circuit, *e.g.*, the iron core of the inductance or in the case of relays, slugs and sleeves for slowing down the rate of flux change. The presence of this secondary circuit renders the above theory invalid due to the fact that the current in the primary of a coil can jump instantaneously to a finite value providing there is present a closely coupled closed secondary circuit. For example, in the circuit of Fig. **5**, on closing the switch the current in the primary circuit can easily be shown to be $\frac{E}{R_1}\left(1-\frac{T_1}{T_1+T_2}\epsilon^{-\frac{t}{T_1+T_2}}\right)$ where T_1 and T_2 are the time constants $\frac{L_1}{R_1}$ and $\frac{L_2}{R_2}$ of the primary and secondary respectively. This means that the current jumps at $t=0$ to $\frac{T_2}{T_1+T_2}$ of its final value.

If the simple Maxwell Inductance Bridge of Fig. **1** be used for the measurement of a coil having a closed secondary circuit, as shown in Fig. **3**, it follows that current balance is impossible, but quantity balance can still be obtained, the conditions being the same as those previously required for current balance. Referring to Fig. **3**, the current in Q on switching on $= \frac{E}{P+Q} + \left(\frac{E}{Q} - \frac{E}{P+Q}\right)\epsilon^{-\frac{t}{Cr}}$

$$\text{where } \tau = \frac{PQ}{P+Q}$$

$$\text{Current in S} = \frac{E}{R_1+S}\left(1 - \frac{T_1}{T_1+T_2}\,\epsilon^{-\frac{t}{T_1+T_2}}\right)$$

$$\text{Volts across Q} = \frac{EQ}{P+Q} + \frac{EP}{P+Q}\,\epsilon^{-\frac{t}{C\tau}}$$

$$\text{Volts across } R_1 = E - \frac{ES}{R_1+S}\left(1 - \frac{T_1}{T_1+T_2}\,\epsilon^{-\frac{t}{T_1+T_2}}\right)$$

Difference = P.D. across the galvanometer

$$= \frac{EP}{P+Q}\,\epsilon^{-\frac{t}{C\tau}} - \frac{EST_1}{(R_1+S)(T_1+T_2)}\,\epsilon^{-\frac{t}{T_1+T_2}}$$

$$\int_0^\infty \text{P.D.} = \frac{EP^2CQ}{(P+Q)^2} - \frac{EST_1}{(R_1+S)}$$

$$= \frac{EP^2CQ}{(P+Q)^2} - \frac{ESL_1}{(R_1+S)^2}$$

$$= \frac{EP^2}{(P+Q)^2}\left(CQ - \frac{L_1}{S}\right), \text{ which is}$$

zero, giving a quantity balance if $\frac{L_1}{C} = QS$.

Similar reasoning shows that with a secondary circuit the Rimington-Maxwell Bridge gives a quantity balance independently of the presence of the secondary circuit, the conditions of balance being as before

$$PR_1 = QS \text{ and } \frac{L_1}{C} = \frac{R_1T^2}{P}$$

This was demonstrated recently by Dr. Turney in J.I.E.E., Vol, 66, p. 382.

The chief advantage of the Rimington-Maxwell Bridge is that a fixed condenser can be used instead of an expensive variable standard, and quantity balance obtained by moving the tapping along the resistance P. A further property of this bridge can, however, be made use of if both the tapping point along P and the condenser are variable. This property is demonstrated below. Referring to Fig. 4, on switching on, the current in the branch Q decays logarithmically as before according to the law

$$i_Q = \frac{E}{P+Q} + \left(\frac{E}{P+Q-T} - \frac{E}{P+Q}\right)\epsilon^{-\frac{t}{C\tau}}$$

$$\text{where } \tau = \frac{T(P+Q-T)}{P+Q}$$

while the current in S obeys the law

$$i_S = \frac{E}{R_1+S}\left(1 - \frac{T_1}{T_1+T_2}\,\epsilon^{-\frac{t}{T_1+T_2}}\right)$$

where $T_1 = \frac{L_1}{R_1+S}$ and $T_2 = \frac{L_2}{R_2}$ are the time constants of the primary and secondary circuits respectively. The voltage across Q is therefore

$$V_Q = \frac{EQ}{P+Q} + \frac{ETQ}{(P+Q)(P+Q-T)}\,\epsilon^{-\frac{t}{C\tau}}$$

and across R_1

$$V_R = E - \frac{ES}{R_1+S}\left(1 - \frac{T_1}{T_1+T_2}\,\epsilon^{-\frac{t}{T_1+T_2}}\right)$$

$$= \frac{ER_1}{R_1+S} + \frac{ES}{R_1+S}\left(\frac{T_1}{T_1+T_2}\right)\epsilon^{-\frac{t}{T_1+T_2}}$$

These must be equal for a current balance, the three conditions necessary being therefore

$$\left.\begin{aligned} \frac{EQ}{P+Q} &= \frac{ER_1}{R_1+S} \\ \frac{ETQ}{(P+Q)(P+Q-T)} &= \frac{ES}{R_1+S}\left(\frac{T_1}{T_1+T_2}\right) \\ \frac{1}{C\tau} &= \frac{1}{T_1+T_2} \end{aligned}\right\}.$$

The first condition is simply the D.C. balance condition that $SQ = PR_1$ while the second and third conditions simplify by substitution to

$$\frac{L_1}{C} = \frac{R_1T^2}{P}$$

$$\text{and } \frac{L_2}{R_2} = \left(\frac{P-T}{T}\right)\frac{L_1}{R_1}$$

The first two conditions are those for quantity balance, while the third condition gives a potential method of measuring the time constant of a secondary circuit for cases where direct measurement is impossible, *e.g.*, the core of a relay.

As quantity balance can be obtained with the first two conditions only, it is necessary to be able to distinguish between quantity and current balance in order to obtain the third condition.

Two methods were found workable. The first was to make use of the " double kick " present with a quantity balance (particularly when using a quick-moving instrument) and to adjust the value of C and the tapping point in P until the movement of the needle was a minimum. The second method made use of a rectifier and reversing switch in series with the galvanometer to cut off half the oscillations in the instrument, and so preventing the bridge being balanced unless all the three conditions for current balance were present.

The use of the Rimington-Maxwell Bridge in this way is extremely tedious, for in obtaining current balance every alteration in the condenser value necessitates a readjustment of the tapping point on P, and many such adjustments are necessary. To avoid the interdependence of adjustment the modified bridge shown in Fig. 6 was devised. In this case steady balance is first obtained; then by adjusting C quantity balance is secured and, finally by adjusting the resistance T in series with the condenser the bridge is balanced for current, no further adjustment of the capacity being necessary.

The conditions for current balance on making or breaking the battery in this bridge can be simply shown by finding the condition which will make the balance independent of frequency as follows:

For current balance

$$QS=\left(\frac{1}{\frac{1}{P}+\frac{1}{T+\frac{1}{j\omega C}}}\right)\left(R_1+j\omega L_1+\frac{\omega^2M^2}{R_2+j\omega L_2}\right)$$

the expressions in brackets being the impedances of the arms AB and CD respectively. Working this out and putting in the steady state balance condition of $PR_1 = QS$ shows that for the bridge to be independent of frequency the conditions $\frac{L_1}{C}=PR_1=QS$ and $\frac{L_2}{R_2}=CT$ must hold.

These conditions are independent of one another and therefore facilitate the use of the bridge. The following shows for the simple case how the introduction of T enables current balance to be obtained without affecting the conditions for quantity balance in any way.

On closing the battery switch the current in Q decays logarithmically from $\frac{E}{Q+\frac{PT}{P+T}}$ to $\frac{E}{P+Q}$ according to the law

$$i_Q=\frac{E}{P+Q}+\left(\frac{E}{Q+\frac{PT}{P+T}}-\frac{E}{P+Q}\right)\epsilon^{-\frac{t}{Cr}}$$

$$\text{where } r = T+\frac{PQ}{P+Q}$$

while in S the current obeys the law

$$i_S=\frac{E}{R_1+S}\left(1-\frac{T_1}{T_1+T_2}\epsilon^{-\frac{t}{T_1+T_2}}\right) \text{ where } T_1=\frac{L_1}{R_1+S} \text{ and } T_2=\frac{L_2}{R_2}$$

The voltage across Q is therefore

$$\frac{EQ}{P+Q}+\frac{EP^2Q}{(QP+QT+PT)(P+Q)}\epsilon^{-\frac{t}{Cr}}$$

and across R_1 is $E-\left(\frac{ES}{R_1+S}-\frac{ES}{R_1+S}\cdot\frac{T_1}{T_1+T_2}\epsilon^{-\frac{t}{T_1+T_2}}\right)$

$$=\frac{ER_1}{R_1+S}+\frac{EST_1}{(R_1+S)(T_1+T_2)}\epsilon^{-\frac{t}{T_1+T_2}}$$

For current-balance the conditions are therefore

$$\left.\begin{aligned}\frac{Q}{P+Q}&=\frac{R_1}{R_1+S}\\ \frac{P^2Q}{(QP+QT+PT)(P+Q)}&=\frac{EST_1}{(R_1+S)(T_1+T_2)}\\ \text{and } \frac{1}{T_1+T_2}&=\frac{1}{C\left(T+\frac{PQ}{P+Q}\right)}\end{aligned}\right\}$$

Simplifying these conditions $QS=PR_1$, $\frac{L_1}{C}=QS$, and $\frac{L_2}{R_2}=CT$ as obtained previously.

Now considering quantity balance: — The P.D. across the galvanometer is

$$\frac{EQ}{P+Q}+\frac{EP^2Q}{(QP+QT+PT)(P+Q)}\epsilon^{-\frac{t}{Cr}}-\frac{ER_1}{R_1+S}+\frac{EST_1}{(R_1+S)(T_1+T_2)}\epsilon^{-\frac{t}{T_1+T_2}}$$

which with the steady condition of $PR_1 = QS$ is

$$\frac{EP^2Q}{(QP+QT+PT)(P+Q)}\,\epsilon^{-\frac{t}{CT}} - \frac{EST_1}{(R_1+S)(T_1+T_2)}\,\epsilon^{-\frac{t}{T_1+T_2}}$$

For zero aggregate quantity in the galvo the integral of the P.D. from $t=0$ to $t=\infty$ must be zero.

$$\therefore \frac{PQC}{P+Q} = T_1 = \frac{L_1}{R_1+S}.$$

from which $\frac{L_1}{C} = SQ$ independent of the value of T.

In practice the accuracy of measurement of L_1 and R_1 is good, but the accuracy of the result for the secondary circuit is limited to about 10%, by the incomplete coupling usually present between the core and winding and probably by the self-capacity. Further, the assumption that the core of a relay can be represented mathematically as a simple secondary winding is only approximate with the result that instead of zero deflection sometimes a minimum has to be taken.

It is of course the time constant of the core which largely determines the release lag of a quick-release relay, while its operation is dependent both on the time constants of the winding and of the core. For the application of the time constants of a relay to the calculation of operate and release time lags, reference may be made to the paper on "The Principles of Relay Timing," by Dr. Turney, loc. cit. Fig. **7** shows the time constant of the core of a typical telephone relay as measured by this method. It will be noticed that it varies with the degree of saturation of the iron and also with the armature air gap. Tests on a relay fitted with a copper sleeve showed that the time constant of the sleeve could be measured fairly accurately, but in the case of a relay fitted with a copper slug at the armature end of the core the incomplete coupling was found to interfere with the balance to a large extent.

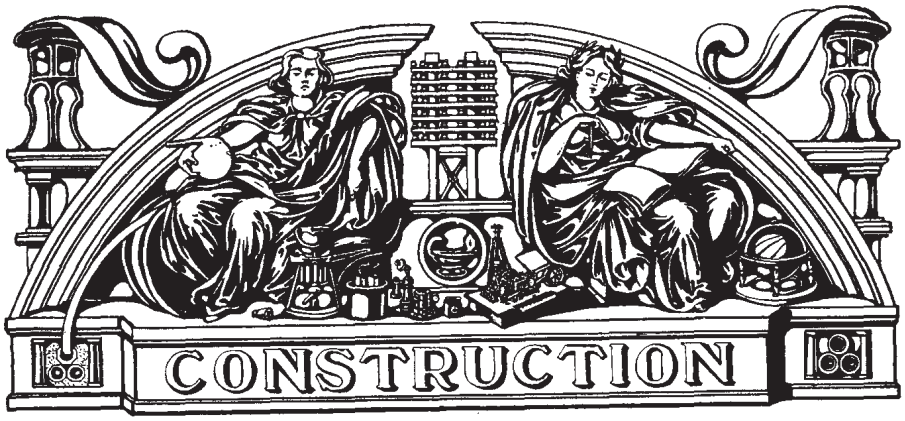
As the eddy current losses in an inductance supplied with A.C. are dependent on the time constant of the eddy current paths in the core the above modification may have an application to A.C. Bridges. It was noticed that the time constant of the core of a Repeating Coil 4006A was about 0.3 milliseconds.

Other types of bridge can be used such as Illovicis' modification of the Maxwell Bridge in a similar manner, but that of Fig. **6** is most convenient in practice as the balance conditions are independent of one another.

Apart from the application of this bridge to the measurement of time constants of the cores, etc., of inductances, the modification enables more exact measurements of the primary inductance to be obtained as the "double kick" effect generally present due to the necessity for quantity balance can be reduced by adjustment of the resistance T to give current balance.

The following table shows the current and quantity balance conditions for the particular types of bridge discussed in this paper:—

	Conditions of Balance.			
	Inductance without secondary circuit.		Inductance with secondary circuit.	
	Quantity Balance.	Current Balance.	Quantity Balance.	Current Balance.
Maxwell Bridge ...	$\frac{L}{C} = QS = PR$		$\frac{L_1}{C} = QS = PR_1$	Not possible
Rimington-Maxwell Bridge	$\frac{L}{C} = \frac{T^2R}{P}$ and $PR = QS$	Not possible	$\frac{L_1}{C} = \frac{T^2R_1}{P}$ $PR_1 = QS.$	$\frac{L_1}{C} = \frac{T^2R_1}{P}$ $PR_1 = QS.$ $\frac{L_2}{R_2} = \left(\frac{P-T}{T}\right)\frac{L_1}{R_1}$
Modified Maxwell Bridge of Fig. 6 ...	$\frac{L}{C} = QS = PR$	$\frac{L}{C} = QS = PR$ and $T=0$	$\frac{L_1}{C} = QS = PR_1$	$\frac{L_1}{C} = QS = PR_1$ $CT = \frac{L_2}{R_2}$



A.C. METHODS OF FAULT LOCALISATION IN TELEPHONE CABLES.

W. T. PALMER, A.M.I.E.E., and M. E. TUFNAIL, Student, I.E.E.

SUMMARY. — Theoretical and practical details are given of the application of audio-frequency alternating current measurements for the purpose of localising faults in paper-core cables, with special reference to the continuously-loaded type of such cables. Methods are given for dealing with the case of a complete breakdown of the insulation of all circuits and for the case of a high resistance fault in one conductor of a pair. It will be seen that when so applied the A.C. methods have many advantages over the D.C. methods and, unlike the latter, the former give absolutely reliable results with errors of less than 1%, from SIMPLE ARITHMETICAL CALCULATIONS.

Introduction.—(1) With the increasing use of lead-sheathed paper-core submarine cables for telephonic links between this country, neighbouring islands and the Continent, there is an ever-increasing risk of the complete breakdown of all circuits of some important route due to the failure of its submarine link. When the lead sheath of such a link is fractured (by anchors, trawls, rocky sea-bed, etc.) the penetration of sea-water and the consequent earthing of every wire is only a matter of hours, or perhaps minutes. Fault localisation by direct current methods then becomes unsatisfactory for several reasons, chief among which ranks the polarisation at the fault. Sometimes a " Varley Loop " test is possible by arranging for a " good " wire *via* another route, but this involves the expenditure of much valuable time, whilst frequently the " good " wire so obtained is unsatisfactory, due to induced currents which adversely affect the galvanometer deflection, and the localisation can only be stated within wide limits. In such cases, when all circuits are badly affected, the A.C. method used as described in Section I. gives results with a much greater degree of reliability than any of the D.C. tests which can be applied.

(2) Another type of fault, difficult to localise and encountered in underground cables more frequently than in submarine cables, is that of a high resistance concentrated at some point in one conductor of a pair. Examples of the likely causes of such faults are badly soldered connections at loading points and at the cable joints. Usually the fault resistance varies rapidly throughout the localisation test and renders the use of D.C. methods difficult and often unreliable, whereas the A.C. method described in Section II. may be applied without loss of accuracy in such cases.

SECTION I.—COMPLETE BREAKDOWN OF ALL CABLE CIRCUITS.

Theoretical Considerations. — Consider the case of a contact fault of resistance F ohms at a distance l nauts from the sending-end of a cable

having otherwise uniformly distributed electrical constants and closed by its characteristic impedance Z_0. See Fig. 1.

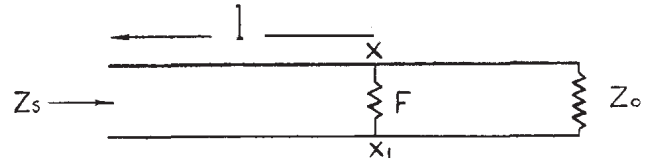


FIG. 1.

The resulting terminating impedance, Z_r, of this arrangement at XX_1 is given by

$$Z_r = \frac{FZ_0}{F+Z_0} \quad \ldots\ldots(1)$$

and the sending-end impedance, Z_s, by

$$Z_s = \frac{Z_0 Z_r \cosh \gamma l + Z_0^2 \sinh \gamma l}{Z_0 \cosh \gamma l + Z_r \sinh \gamma l} \quad \ldots\ldots(2)$$

where Z_0 is the characteristic impedance of the cable,

γ is the propagation constant of the cable $= \beta + j\alpha$ and

β is the attenuation constant,

α is the wave-length constant.

This equation (2) can be evaluated from a knowledge of the value of F and of the primary constants R, L, G, and C. (See Table I.). In the case of a short-circuit, F = 0, then equation (2) becomes

$$Z_s = Z_0 \tanh \gamma l \quad \ldots\ldots(3)$$

From (3) Z_0 is considered to be constant and to have zero angle (a condition which is approximately true in the case of a continuously-loaded cable for frequencies within the audio-range considered) it can be shown that the sending-end impedance, Z_s, will pass through maximum points when

$$2\alpha l = \pi, 3\pi, 5\pi \ldots \text{ etc.} \quad \ldots\ldots(4)$$

Hence the frequency f_1 at which the first maximum point occurs in the ideal case can be found from the expression

$$2\alpha_1 l = 2l\sqrt{\tfrac{1}{2}\{\sqrt{(R^2+\omega_1^2L^2)\omega_1^2C^2} + \omega_1^2LC\}} = \pi \ldots(5)$$

where α_1 = wave-length constant at a pulsatance $\omega_1 = 2\pi f_1$,

R = resistance per unit length,

L = inductance per unit length and

C = capacity per unit length.

From equation (5) it can be readily shown that the value of f_1 is given by the expression

$$f_1 = \frac{\pi}{4l\sqrt{l^2R^2C^2 + \pi^2LC}} \quad \ldots\ldots(6)$$

Thus knowing the value of f_1 by measurement, it is possible to use equation (6) or the more approximate and convenient equation (7) following, to calculate the distance to the fault F.

Approximations to Equation (6).

(a) The Loaded Cable. — If $l^2R^2C^2$ be neglected as a first approximation, the expression becomes

$$f_1 = \frac{1}{4l\sqrt{LC}} \fallingdotseq \frac{K}{2l} \quad \ldots\ldots(6A)$$

where K is a constant.

Again from equation (4) it is seen that the theoretical second maximum point occurs at a frequency $f_2 = 3f_1$ and hence $f_2 - f_1 = 2f_1$. If, therefore, we write f as the frequency interval between successive maximum points we obtain

$$f = 2f_1 \fallingdotseq \frac{1}{2l\sqrt{CL}} \fallingdotseq \frac{K}{l} \quad \ldots\ldots(7)$$

It is important to notice that the first maximum point may be considered to occur at a frequency $\frac{1}{2}f$ from zero, *i.e.*, at half the mean frequency interval.

Equation (7) is essentially true for all values of F small enough to cause pronounced periodic maximum points to occur in the Z_s/f curve, and can be obtained in another way as follows:—

*Electrical energy will be partly reflected at the fault F and part will travel to the distant end. The phase of the reflected portion at any given frequency, when it reaches the sending-end, will have changed by an angle $(2\alpha_1 l + \phi_1)$ radians, where ϕ_1 = change in phase produced at the fault F,

α_1 = wave-length constant at the frequency f_1 considered

and l = distance to the discontinuity F.

Then if two successive maximum points, which are found in the value of the sending-end

* *See I.P.O.E.E. Paper No. 76 (1919) by C. Robinson and R. M. Chamney.*

impedance as it changes with frequency, occur at frequencies f_1 and f_2 cycles per second respectively, we have

$$(2\alpha_2 l + \phi_2) - (2\alpha_1 l + \phi_1) = 2\pi$$

and $$\therefore \quad l = \frac{\pi + \frac{1}{2}(\phi_1 - \phi_2)}{\alpha_2 - \alpha_1} \qquad \ldots\ldots\ldots\ldots(8)$$

If we assume $\phi_1 = \phi_2$, and in the case of the continuously loaded cable with contact fault this is very nearly true (See Table I.), we get

$$l = \frac{\pi}{\alpha_2 - \alpha_1}$$

or, in the case of the loaded cable, writing $f = f_2 - f_1$ and $\alpha_1 = 2\pi f_1 \sqrt{LC}$ we have

$$l \fallingdotseq \frac{1}{2f\sqrt{CL}} \qquad \ldots\ldots\ldots\ldots(9)$$

which is the same as equation (7).

(*b*) *Unloaded Cable.*—In this case, putting L = o in equation (6) we get

$$f_1 = \frac{\pi}{4l^2RC}$$

and $$\therefore \quad l = \sqrt{\frac{\pi}{2RCf}}$$

Practical Considerations.—A convenient form of bridge for measuring the sending-end impedance is shown in Fig. **2**(*a*). With this form of bridge the actual bridge resistance readings can be used in place of the calculated impedance for the purpose of fault localisation. [See Pp. 45/6 B(I) on Experiments made at Dover]. Equation (7) is best used in the form

$$l = K \div f \qquad \ldots\ldots\ldots\ldots(10)$$

where K is an empirical constant determined by introducing at a known distance l along the cable circuit (generally the distant end of the cable) a contact resistance across a selected pair. The sending-end impedance curve is then measured over a range of frequency, and from this curve a value for f is computed. Hence from equation (10) we get K. When a breakdown occurs a sending-end impedance-frequency curve is taken on the same pair and the new mean frequency interval f between successive maxima of impedance is computed. By the use of equation (10) again the distance to the fault can be found. The advantages of using equation (10) are that any lack of uniformity in the normal cable constants and any difference between the values of ϕ_1 and ϕ_2 in equation (8) above, are taken into account to some extent when the value of K is found from experiment.

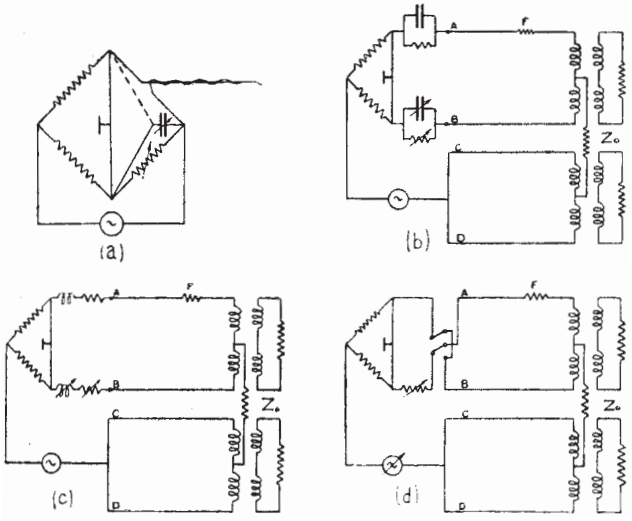


FIG. 2.

(*a*) Sending end Impedance Bridge.
(*b*) Impedance unbalance Bridge, using capacity and resistance.
(*c*) Impedance unbalance Bridge, using inductance and resistance.
(*d*) Zero Reactance Bridge.

In obtaining the value of f it is not necessary in any case, when obtaining the requisite impedance-frequency curve, that all the test frequency intervals be very small, since they are only required to determine the *number* of maximum points occurring in the frequency range considered. Then, if n such maximum points are found, the nth maximum only need be carefully explored at very small test frequency intervals, in order to obtain as accurately as possible the value f_n at which it occurs. The value of the mean interval, f, is then found from the expression

$$f = f_n \div (n - \tfrac{1}{2}) \qquad \ldots\ldots\ldots\ldots(10A)$$

since the first maximum occurs at half an interval, f, from zero.

In this expression the value of f_n should be as high as is consistent with its accurate determination. The following test results will illustrate the application of the method and show the degree of accuracy to be expected in localisation. They also indicate those cases where some precaution, and slight modification to the simple procedure outlined, may be necessary to obtain the most accurate results.

EXAMPLES OF TEST RESULTS.

(A). *Anglo-French (1926). Continuously-Loaded, Submarine Telephone Cable.*

This cable has a total length of 50.5 nauts between Canterbury and Boulogne. The value of K was obtained by tests from Canterbury on a selected side circuit, in the following manner:

The selected pair was looped at Boulogne to another pair, the circuit so formed being terminated at Canterbury with 400 ohms (the approximate characteristic impedance of the line). A contact resistance of 50 ohms was connected across the circuit at Boulogne, *i.e.*, at 50.5 nauts, and the resulting sending-end impedance then measured over a range of frequencies. The bridge-resistance readings so obtained are shown in Fig. **3** plotted against frequency. This figure

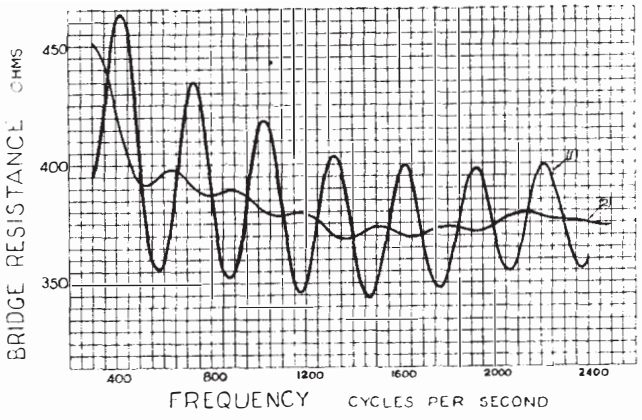


FIG. 3.—ANGLO-FRENCH (1926) CABLE.

Results for side Circuit with (1) 50 ohms contact fault at $l = 50.5$ nauts and (2) terminated by 400 ohms at Boulogne.

also gives the Z_0/f curve for the same pair terminated by 400 ohms at Boulogne. The 8th maximum occurring after zero frequency was carefully explored at very small frequency intervals and from these resistance readings were subtracted the corresponding readings obtained when the 50 ohms was removed, *i.e.*, from the faulty impedance characteristic subtract the normal impedance characteristic over the frequency range considered. (See also Pp. 47/8 C). The value of the frequency at which the 8th maximum value of the differences occurs is 2208 c.p.s. (f_8), from which $f = 294$ c.p.s. and $K = 14870$.

NOTE.—The principle of subtraction of the normal impedance curve of a circuit from the corresponding impedance curve of that circuit when faulty is essential in certain cases (and in general leads to greater accuracy of localisation) and is discussed in paragraph C. It is therefore desirable to have recorded an exact impedance frequency curve of a pair, prior to breakdown, if this method of localisation is to be applied with the greatest possible accuracy. Some interesting results are given in Section III., of the seasonal change of characteristic impedance, measured over a period of a year, for cables of the type under consideration.

Two examples of complete breakdowns occurring in this cable are, one on 17th November, 1928, and another on 9th December, 1929. In the former case an A.C. test gave 6 maximum points between zero and 2000 c.p.s., the 6th maximum being carefully explored and occurring, after subtraction of the normal ordinates, at 1696 c.p.s. From equation (10A) $f = 1696 \div 5\frac{1}{2} = 308.2$ c.p.s. and from equation (10) *the A.C. localisation gives 48.2 nauts from Canterbury. The actual distance to the fault was 48.34 nauts from Canterbury, i.e.*, an error of 0.3%.

In the second case, more than twelve months after the first, the same value of K was used and *the A.C. localisation gave 41.7 nauts to the fault from Canterbury. The actual distance was within 0.5 naut* of that figure.

In both the above cases there was a varying E.M.F. in the fault of about 0.2 volt and with D.C. tests considerable polarisation took place, causing the fault resistance to vary considerably from a mean value of about 300 ohms. The effect of these and other variations on the accuracy of the A.C. test was studied at Dover Submarine Cable Depot, on some spare lengths of continuously-loaded cable, and the results are given in Pp. 45/6 B following:—

(B). *Experiments Made at Dover.*

(1) *Use of Bridge Resistance Readings for the Determination of K.*—It was found that the results obtained for K by plotting the bridge resistance readings against frequency gave essentially the same results as those obtained

by plotting Z_0. The difference between the value by plotting Z_0 in no case exceeded 0.5%. This is principally due to the fact that in the neighbourhood of all maximum impedance points the reactance part of the impedance is practically zero. Further, the effect of this difference is decreased by using the bridge resistance readings when localising faults and employing the value of K obtained from a bridge-resistance-frequency curve.

(2) *Tests made with Different Values of F.*—A family of several of the curves obtained with different values of F at 10.2 nauts is shown in Fig. **4**. It will be noticed that the mean interval

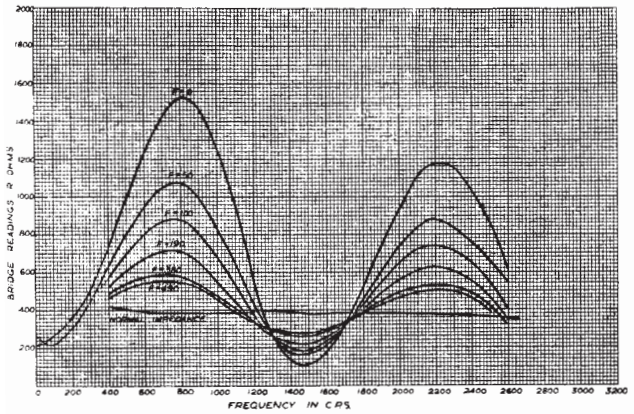


FIG. **4**.—RESULTS OBTAINED WITH CONTACT FAULTS OF VARIOUS VALUES AT THE SAME DISTANCE FROM THE TESTING END.

slightly increases as F increases and this indicates that the exact value of K (for the higher values of fault resistance) will be slightly greater than that for the lower values of F. The mean value of K, however (14,000), is not as much as 1% different from the extreme values likely to occur in practice. The amplitudes (A) of the first maximum points of these curves, after subtraction of the normal impedance bridge readings, are shown plotted against values of F in Curve 1, Fig. **5**. Curve 2 in that figure is a similar example in which $l = 20.95$ nauts.

As the distance l to the fault increases the slope of the A/F curve everywhere decreases until, in the limit, when l has such an attenuation length as to give the infinite line condition, $A = 0$ at all frequencies and the curve coincides with the axis of F.

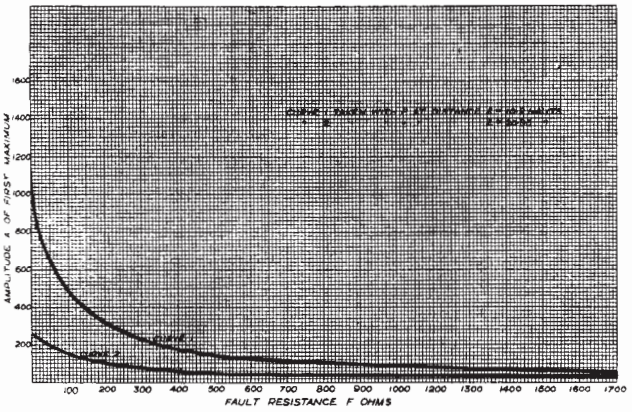


FIG. **5**.—VARIATIONS OF AMPLITUDE OF FIRST IMPEDANCE MAXIMUM (A) WITH FAULT RESISTANCE (F).

(3) *Tests made with Faults at Different Distances, l, from the Testing End.*—Fig. **6** shows the relation between the amplitude, A, and the distance, l, obtained with a fault resistance of 380 ohms introduced at various distances from the testing end.

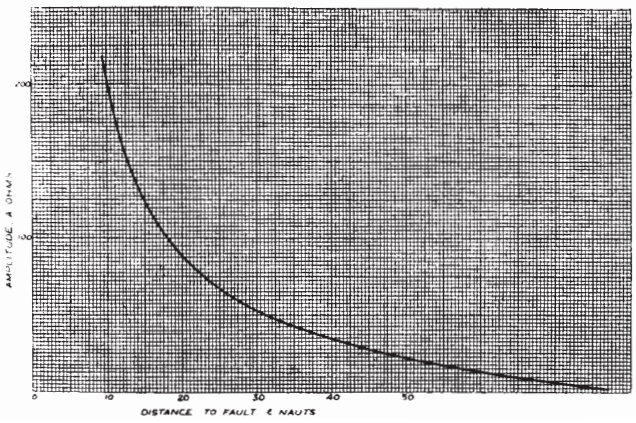


FIG. **6**.—VARIATIONS OF FIRST MAXIMUM OF IMPEDANCE (A) WITH DISTANCE TO FAULT (*l*).
Fault resistance constant and = 380 ohms.

TABLE I.

COMPARISON OF THEORETICAL AND MEASURED SENDING-END IMPEDANCE CHARACTERISTICS FOR CIRCUIT WITH CONTACT FAULT. ANGLO BELGIAN (1926) TYPE CABLE.

DISTANCE TO FAULT = 10.2 NAUTS.

Fault Resistance F ohms.	Frequency f c.p.s.	Calculated Sending-End Impedance Z_s Vector ohms.	Measured Sending-End Impedance Z_s Vector ohms.	Calculated Frequency at Maximum Points f_1 and f_2	Calculated Values of ϕ_1 and ϕ_2	Calculated Values of K.
0	637	1246 | 20° 15	1295 | 16° 30′	716	| 0° 17′	14,910
	716	1479 / 8° 48	1425 / 8° 20′			
	796	1242 / 39° 5	1195 / 38° 20′			
	851	983 / 51° 41	960 / 50° 40′			
	2108	1066 | 19° 21	1015 / 19° 30′	2177	| 0° 31′	
	2188	1173 / 6° 22	1165 / 0° 0′			
	2267	1004 / 30° 28½	1035 / 29° 0′			
1000	637	470.5 / 6° 35½	470 / 8° 10′	670	| 5° 43′	15,260
	676	471.1 / 7° 50	470.5 / 8° 45′			
	716	470.1 / 11° 14	468.5 / 10° 10′			
	2108	445.8 | 2° 34½	438.3 / 1° 50′	2167	| 1° 50′	
	2148	446.9 / 3° 50½	441.5 / 3° 20′			
	2188	446.8 / 4° 53½	442.2 / 4° 55′			
	2211	445.6 / 5° 45	442.0 / 5° 40′			
	2267	439.3 / 7° 53½	439.7 / 7° 20′			

(4) *Effect of Variation of Fault Resistance during the Period of Testing.*—The effect of a large and rapid variation of the fault resistance on the interval f is best seen by reference to Fig. **7** and from those results it will be seen that

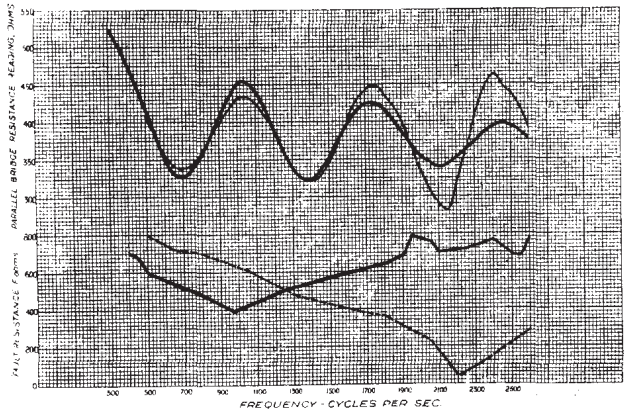


FIG. **7.**—BRIDGE RESISTANCE FREQUENCY CURVES OBTAINED WITH FAULTS VARYING IN VALUE THROUHHOUT THE TEST AS SHOWN BY LOWER CURVES.

the error in localisation would be relatively small since the interval of the maximum points is not seriously affected. Further, the error could be decreased by repeating the tests over the selected maximum (*a*) with increasing test frequencies, (*b*) with decreasing test frequencies, and a mean value of f computed from the results.

(5) *Effect of E.M.F. and Earth Faults.*—Tests made with wet faults by means of a small piece of damaged cable, immersed in sea-water, inserted at known distances l from the testing end, showed no appreciable effect on the accuracy of localisation. The E.M.F. at the fault varied from 0.1 to 0.3 volt and the resultant contact fault resistance from about 10 to 30 ohms. The insulation resistance of the circuit to earth was low and neither this feature nor the effect of E.M.F. and polarisation, affects the accuracy of localisation.

(C). *Isle of Wight (1928), Coil-loaded, Submarine Telephone Cable.*

This cable was tested for K through suitable building-out networks and K found to be 8570.

Fig. **8** (Curve A) shows the normal impedance curve of the selected circuit together with the impedance curve obtained after the introduction of a contact fault of 20,000 ohms at a distance of 22.4 nauts from the testing end (Curve B). The difference between these two curves (amplitudes A) is shown plotted in Fig. **8** (Curve C). The mean interval f is much easier to obtain from Curve C than from B and is 393 c.p.s. Thus the localisation is 22 nauts.

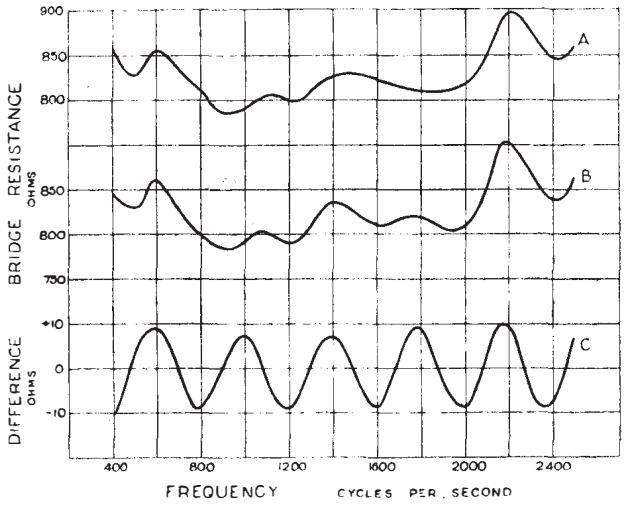


FIG. 8.—ISLE OF WIGHT (1928) COIL-LOADED SUBMARINE CABLE.

(A). Normal Impedance (Bridge Resitance readings).
(B). Impedance with 20,000 ohm fault at 22.4 nauts (do.).
(C). Difference Curve B—A.

NOTE.—The Z_0/f curve obtained with a fault in the line actually represents the normal impedance vector of the line, plus a rotating vector due to reflection. If the effect of this latter vector is small compared with the variations occurring in the normal impedance curve, the shape of the resultant impedance curve will not be sufficiently definite to give an accurate value for the required interval f. In such a case it is necessary to subtract the ordinates of the normal curve from those of the faulty, or resultant, curve and the curve of difference so obtained will give a clearly defined value for f. The example just given and shown in Fig. **8** will illustrate this point.

(D). *Isle-of-Man (1929), Continuously-Loaded Cable—Underground Portion. Case of One Maximum only occurring within the Frequency Range considered.*

This is a case where only one impedance maximum occurs within the audio-range and an approximate localisation can be obtained from the relation

$$2a_1 l = \pi$$
$$i.e.,\ 2f_1 l = K$$
$$\text{or} \quad l = K \div 2f_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Owing, however, to the relatively large shift of the frequency of the first maximum impedance with different values of fault resistance (see Fig. **4**) unless some allowance is made for this effect an error of localisation of as much as 10% may be caused. Such errors, due to the variation of f_1 with F (and thus with A), can be considerably lessened by obtaining experimental data on shorter lengths of cable in the works or on spare lengths of cable, and Fig. **9** represents such data obtained for the Anglo-Belgian (1926) type cable, where values of f_1 are shown plotted against amplitude, A, for distances up to 10 nauts, beyond which equation (7) may be employed. In obtaining this data it is only necessary to draw a few of the curves from actual experiments on lengths available and interpolate for the intermediate curves.

An example of the use of Fig. **9** is supplied by the Isle of Man (1929) land cable which has approximately the same electrical constants as the Anglo-Belgian (1926) cable. This cable became faulty due to water penetration. In this case an impedance test showed that $f_1 = 1174$ c.p.s. and $A = 1485$ ohms. These values of f_1 and A are the co-ordinates of a point in Fig. **9** and the curve passing through this point is seen to be one corresponding to a distance of $l = 7.05$ nauts, an error of 0.5%, since the actual fault was found at a distance from the testing end of 7.01 nauts. If equation (11) be used, however, taking $K = 14940$, the localisation is $l = 6.37$ nauts which is an error of 9%.

SECTION II.—HIGH RESISTANCE IN ONE CONDUCTOR.

(*a*) *Sending-end Impedance Method.*—Fig. **10** represents a high resistance fault F, distant l

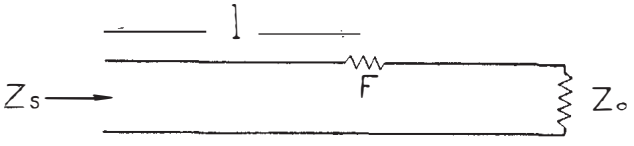


FIG. **10**.

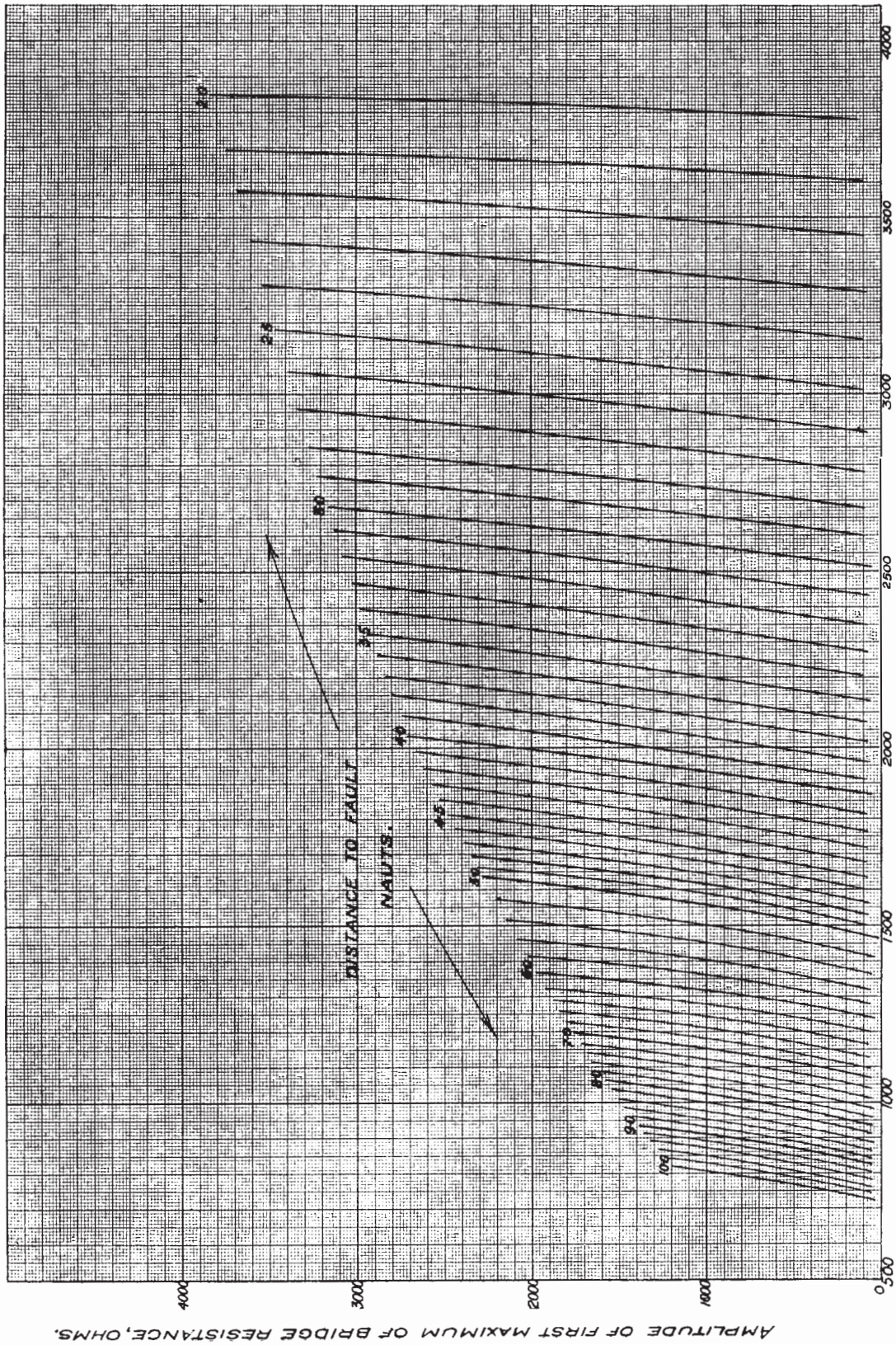

AMPLITUDE OF FIRST MAXIMUM OF BRIDGE RESISTANCE, OHMS.
0
500
1000
2000
3000
4000
1500
2500
3500
FREQUENCY OF FIRST MAXIMUM OF BRIDGE RESISTANCE. C.P.S.
DISTANCE TO FAULT
NAUTS.
20
25
30
35
40
45
50
60
70
80
90
100

FIG. 9.

from the sending-end of a cable, having otherwise uniformly distributed constants and closed by its characteristic impedance Z_0. Following the method adopted in Section I. it can be shown that sending-end impedance frequency curve will pass through successive maximum points when

$$2\alpha l = 2\pi,\ 4\pi,\ 6\pi\ \ldots \text{ etc.} \quad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Hence a similar relationship holds between the distance l and the frequency interval f to that given in equation (7) and this equation is essentially true for all values of F large enough to cause pronounced maximum points to occur in the Z_s/f *difference* curve. To localise such a high resistance fault therefore by this method, the procedure is as follows:—

(1) Use equation (10) in the form

$$l = K_1 \div f \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

where the value of K_1 is found by experiment for a selected pair as in Section I. (See note below). This may be done prior to the development of a fault or at the time of localisation by taking K for the neighbouring pair in the cable.

(2) Obtain a value of f from bridge resistance readings of the Z_s/f curve of the faulty circuit and from equation (13), using the above value of K_1, obtain the localisation l.

NOTE.—Whereas for the case of a contact fault the first maximum point f_1 occurring from zero frequency is given by a value equal to one-half the frequency interval, in the case of a high resistance fault the value f_1 is equal to a complete frequency interval. Hence in computing the value of f for any given Z_s/f curve, where n maximum points occur after zero frequency, it is necessary to use the expression

$$f = f_n \div n \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Deformation.—If the conductor resistance fault occurs so near the sending-end that only one or two maximum points, due to the fault, occur, it will be noticed that subsidiary undulations are present in the Z_s/f curve which "deform" the curve from its theoretical shape. This effect is termed "deformation" and an illustration of the effect is given in Fig. **11**. The deformation of the curve for the main reflection from the fault is due to secondary reflections influenced by:—

(1) The value of the terminating impedance.
(2) The length of cable between the fault and the distant termination.

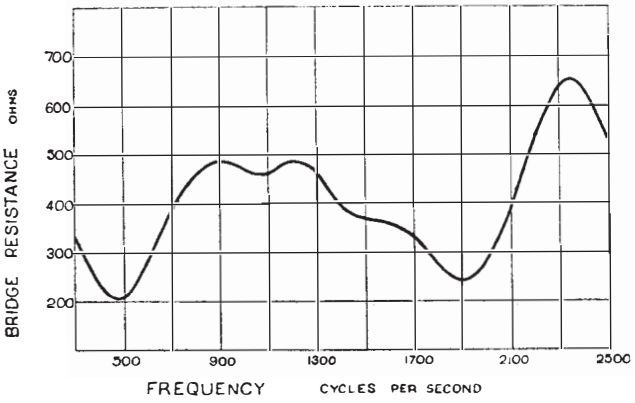


FIG. 11.—EXAMPLE OF DEFORMATION PRODUCED IN $Z_s - f$ CURVE WHEN F IS NEAR THE TESTING END.

The influence of (1) is felt principally upon the magnitude of the subsidiary reflections, whilst (2) chiefly effects their phase. It is not practicable to obtain a satisfactory rigorous mathematical treatment, or a complete experimental investigation of these effects, in order to make use of the first maximum part of the sending-end impedance curve for the localisation of near-up faults (as in the case of near-up contact faults—see Fig. **9**). Moreover, the zero reactance method, described later, minimizes the necessity for such an investigation.

*(*b*) *Impedance Unbalance Method.*—Fig. **2** (*b*) and (*c*) shows two possible arrangements of the impedance unbalance bridge required to localise a high conductor resistance fault, using the phantom circuit as a reference circuit. Resistance and reactance are inserted in the bridge to produce in the telephone circuit a current equal in magnitude, but opposite in phase, to that produced by the faulty circuit. A similar equation to that of (13) can be used, viz.,

$$l = K_2 \div f \quad \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

where K_2 is a constant determined by introducing a high resistance at the distant end of the cable (or at some other known distance along the

* "*Telephone Circuit Unbalances,*" *by C. P. Ferris and R. G. McCurdy. Bell Reprint No. B-134-1. July, 1925.*

cable) in a similar circuit to that of the faulty circuit, plotting against frequency the real or imaginary component of the unbalance impedance required at the bridge and obtaining the mean frequency interval, f, of the maximum points. This experimental determination of K allows to some extent for different localised phase-angle changes at different frequencies and for slight variations of V_1 and V_2 produced by changes in the electrical constants with frequency —where V_1 and V_2 are the electric wave-velocities of the faulty and reference circuits respectively and, theoretically,

$$K_2 = \frac{V_1 V_2}{V_1 + V_2}$$

If $V_1 = V_2 = V$ we get $K_2 = \frac{V}{2}$ where V is the velocity of electric-wave propagation along the circuit tested and applies to the case considered in Section I. Thus these methods are only strictly accurate. (1) If V_1 and V_2 are absolutely constant over the range of frequencies considered. (2) If the localised phase-angle change, ϕ, produced at the fault itself is also constant over that frequency range.

The value of f with this impedance unbalance method is found by using equation (14), as for the sending-end impedance method and it will be realised that the former is essentially an adaptation of the latter method. It has about the same degree of accuracy when more than one maximum point is obtained in the audio-frequency range, but it suffers from the same disadvantage of deformation when applied to faults so near the testing end that only one or two maximum points are obtained.

The arrangement in Fig. 2(*b*) involves some calculation to obtain the real parts of the unbalance impedances and a more convenient arrangement is that using inductance and resistance, Fig. 2(*c*), since in that case the bridge resistance readings represent these real values and can be plotted directly without calculation. This will not give essentially different results from those obtained with capacity and resistance.

(*c*) *Zero Reactance Method.*—The necessary arrangement of apparatus is shown in Fig. 2(*d*) and, in addition to the equal ratio arms, consists simply of a resistance R, which can be placed in series with the good conductor or in series with the faulty conductor by means of the reversing switch S. The value of R and the frequency of supply are adjusted simultaneously until silence is obtained in the telephone. The frequency is then increased or decreased and R readjusted until the next silent point is obtained. This operation is repeated throughout the audio-range and each successive frequency so obtained indicates that the wave propagated to and from the fault has passed through 2π radians (as indicated by successive maximum impedance points in Section I. and II.). By reversing the switch S, a second set of frequencies can be obtained having, theoretically, the same frequency interval as the first set but being of intermediate values. All the zero reactance frequencies can be represented by $2n\pi$ where $n = 1, 2, 3, 4 \ldots$ etc., for one position of the switch and $n = \frac{1}{2}, 1\frac{1}{2}, 2\frac{1}{2}, 3\frac{1}{2}, \ldots$ etc., for the other position of the switch and vice-versa.

Let the frequency of zero reactance points as they occur from zero frequency be $f_1, f_3, f_5 \ldots$ for one position of S and $f_2, f_4, f_6 \ldots$ for the other position.

Let f be the mean frequency interval for use in the equation

$$l = K_3 \div f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

where K_3 can be obtained by experiment. It has been found that the best value of f to be used in equation (16) is obtained by neglecting altogether the value of f_1 (see Fig. **12**) and computing the value of $f_{2n} \div n$ where $n = 1, 1\frac{1}{2}, 2, 2\frac{1}{2} \ldots$ etc. The value of n is made as great as possible consistent with the accurate determination of f_{2n}.

Some experimental results are given here to illustrate the application of the method:—

TABLE II.

DISTANCE TO FAULT = 20.95 NAUTS.
VALUE OF $K_3 = 13{,}780$ — OBTAINED WITH TEST RESISTANCE OF 500 OHMS.

F ohms.	f c.p.s.	Localisation in nauts.	Error %	
2	643	21.43	+2.3	Reduced by taking K_1 with test resistance of 50 ohms. See Table III.
5	646	21.33	+1.8	
10	646	21.33	+1.8	
50	645	21.36	+1.9	
200	654	21.07	+0.57	
500	654	21.07	+0.57	
∞	661	20.85	−0.47	

TABLE III.

DISTANCE TO FAULT=20.95 NAUTS.
VALUE OF K_3=13,510—OBTAINED WITH TEST RESISTANCE OF 50 OHMS.

F ohms	f c.p.s.	Localisation in nauts.	Error %	
2	643	21.01	+0.29	
5	646	20.91	−0.19	
10	646	20.91	−0.19	
50	645	20.95	nil	Reduced by taking K_1 with test resistance of 500 ohms. See Table II.
200	654	20.66	−1.4	
500	654	20.66	−1.4	
∞	661	20.44	−2.4	

Tests made at Dover Submarine Cable Depot on Spare Lengths of the Anglo-Belgian (1926) Cable. K_3=13,780, obtained with test resistance of 500 ohms.

(1) A summary of the results for a 500-ohm conductor resistance fault when introduced at various distances from the testing end, is contained in Fig. **12**. The different circuit lengths

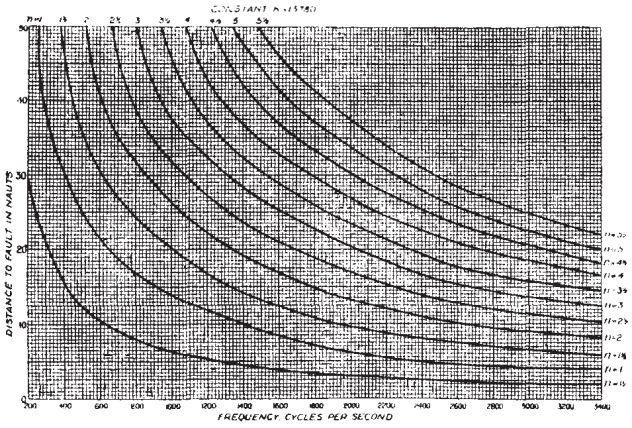


FIG. 12.—ZERO FREQUENCIES V. DISTANCE.

were obtained by looping back pairs and terminating the circuits by the characteristic impedance as for the tests given in Section I.

Two particular examples are as follows:—

(2) *Distance to Fault=12.57 nauts, F=500 ohms.*

In this case f_{2n}=3276 c.p.s. and n=3. Hence f=1092 and the localisation given is $l=\frac{13780}{1090}$ =12.62 nauts, an error of 0.4%.

(3) *Distance to Fault=4.19 nauts, F=500 ohms.*

The value of f_{2n}=3312 c.p.s. and n=1. Hence f=3312 and the localisation given is $l=\frac{13780}{3312}$ =4.17 nauts which is an error of 0.5%.

Effect of Fault Variation.—To illustrate the effect of the fault resistance on the accuracy of localisation some results are given in Table II. for a case in which the effect was most marked. It will be noticed that a fault of 2 ohms was easily localisable at a distance of about 21 nauts, but that in such a case of a low value fault the experimental value of K_3 should be taken with a lower test resistance than 500 ohms and the error of localisation decreased. See Table III.

The accuracy of the zero reactance method depends on the accuracy with which f_{2n} can be determined, and the smallest value of F which can be localised is limited by the magnitude of the reflected wave compared with resultant of the reflections received at the bridge from the existing distributed unbalances normally in the cable. Thus in any balanced cable a conductor resistance fault of sufficient magnitude to cause cross-talk which interferes with the working of a circuit can be localised by the zero-reactance method. Further, this method possesses the following advantages over the methods given in (*a*) and (*b*):—

(1) It is simpler and quicker.
(2) It can be used for faults near the testing end where the other two methods are less accurate due to deformation.
(3) The zero-reactance frequencies can be quite definitely found, whereas the maximum points used in (*a*) or (*b*) are extremely difficult to obtain definitely, especially when the value of fault resistance is low.

SECTION III.—EFFECTS OF SEASONAL TEMPERATURE VARIATIONS ON THE ACCURACY OF FAULT LOCALISATION.

Temperature change produces a much greater percentage change on the D.C. resistance of a cable than upon the inductance or capacity. See Figs **13** and **14**. It follows for the case of a telephone route over which the temperature is

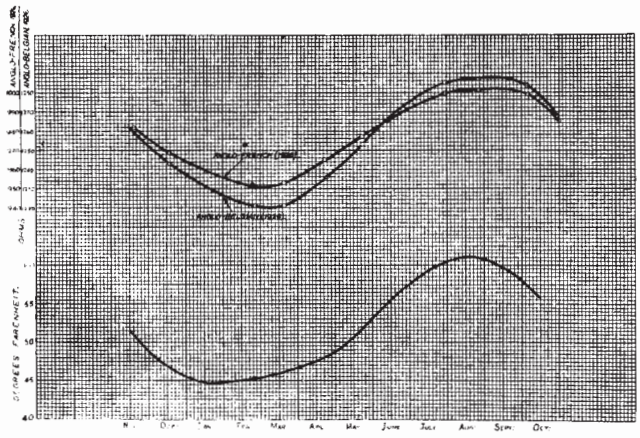


FIG. 13.—SEASONAL VARIATIONS OF D.C. RESISTANCE OF SUBMARINE CABLES AND MEAN SEA TEMPERATURE.

not uniform (such as a route which includes a submarine length in addition to subterranean lengths) that the resulting distribution of conductor resistance with length will have greater non-uniformity than either the distribution of inductance or capacity. Therefore when D.C. resistance tests are made, if the temperature difference between two parts of the same route be appreciable, the use of a mean resistance per unit length (calculated from the measured total resistance divided by the total cable length) for the purpose of converting ohmic distance to actual distance, may lead to considerable errors of localisation. On the other hand, when A.C. localisation tests are applied as described in the previous Sections, the constant K which is used depends for its magnitude principally upon the inductance and capacity of the cable. Since these constants show very little change with temperature (see lower curves in Fig. **14**) it is seen that the corresponding change in the value of K is extremely small and hence the temperature distribution over the route does not, as in the D.C. case, lead to serious errors of localisation.

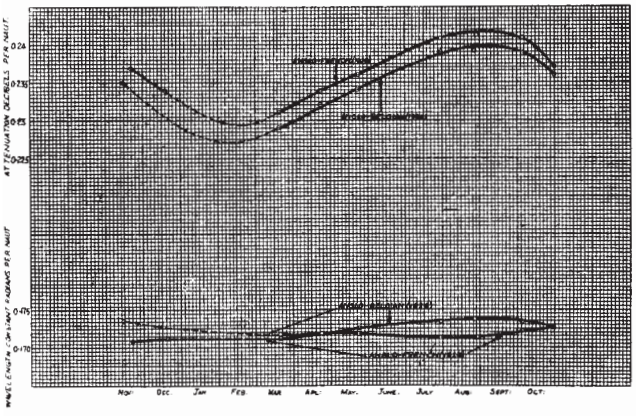


FIG. 14.—SEASONAL VARIATIONS OF ATTENUATION AND WAVE-LENGTH CONSTANTS OF SUBMARINE CABLES.

An example of the possible error due to temperature difference is given here for the case of a D.C. localisation test.

Example. A cable consists of 10 nauts of land cable and 40 nauts sea cable. The mean temperature difference between land and sea is 8°C. During the existence of a fault a Varley loop test gives a steady Varley reading of 810.6 ohms, and the " good " loop resistance is 965.

From these figures the mean conductor resistance per naut loop is 19.3 ohms and this gives a localisation of 8.0 nauts. Taking a temperature coefficient for copper of 0.004 ohm per degree Centigrade the corrected distance to the fault is 7.80 nauts, *i.e.*, an error of 2.6% when using a mean conductor resistance per unit length in the absence of information concerning the distribution of temperature over the route.

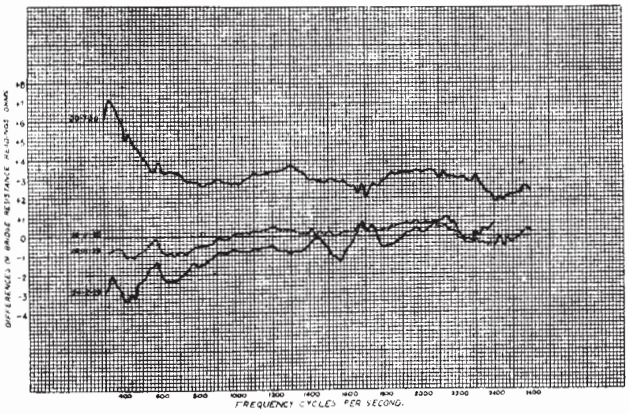


FIG. 15 REPRESENTS EXTREME CHANGES OF Z_s/f CHARACTERISTIC AS MEASURED ON ANGLO-BELGIAN (1926) CABLE FOR A PERIOD OF ONE YEAR.

Seasonal Changes of D.C. Resistance, Wave-Length Constant, and Characteristic Impedance.

Some interesting data has been obtained for two Continental paper-core submarine telephone cables as a result of measurements taken each month for the period of a year. A brief summary is as follows :—

D.C. Resistance.—Fig. **13** shows the variation

of this feature plotted against time together with some mean sea-temperatures plotted to the same base. The maximum variation from a mean value of the resistance is 5%.

Wave-Length Constant.—See lower curves in Fig. **14**. In this case the maximum variation from a mean value is 0.5%, *i.e.*, only one-tenth the corresponding figure for the D.C. resistance. In Fig. **14** is also shown the variation of the attenuation constant of the two cables throughout the year.

Characteristic Impedance.—See Fig. **15**. This shows the case for the Anglo-Belgian (1926) cable. The change in the magnitude of the impedance is shown in these curves as differences between the original bridge resistance readings obtained on 19-11-28 and those obtained in subsequent tests. The original test results are therefore represented by the straight line drawn through zero resistance. These tests show that the seasonal variation of the characteristic impedance is small enough to permit the use of the same Z_0/f curve for localisation purposes at any season throughout the interval between successive repairs. It is interesting to note that the impedance of the circuit considered was not different at any frequency, one year after the first test, by more than 0.3%.

EFFECTS OF EARTHQUAKE ON TELEGRAPH AND TELEPHONE COMMUNICATIONS.

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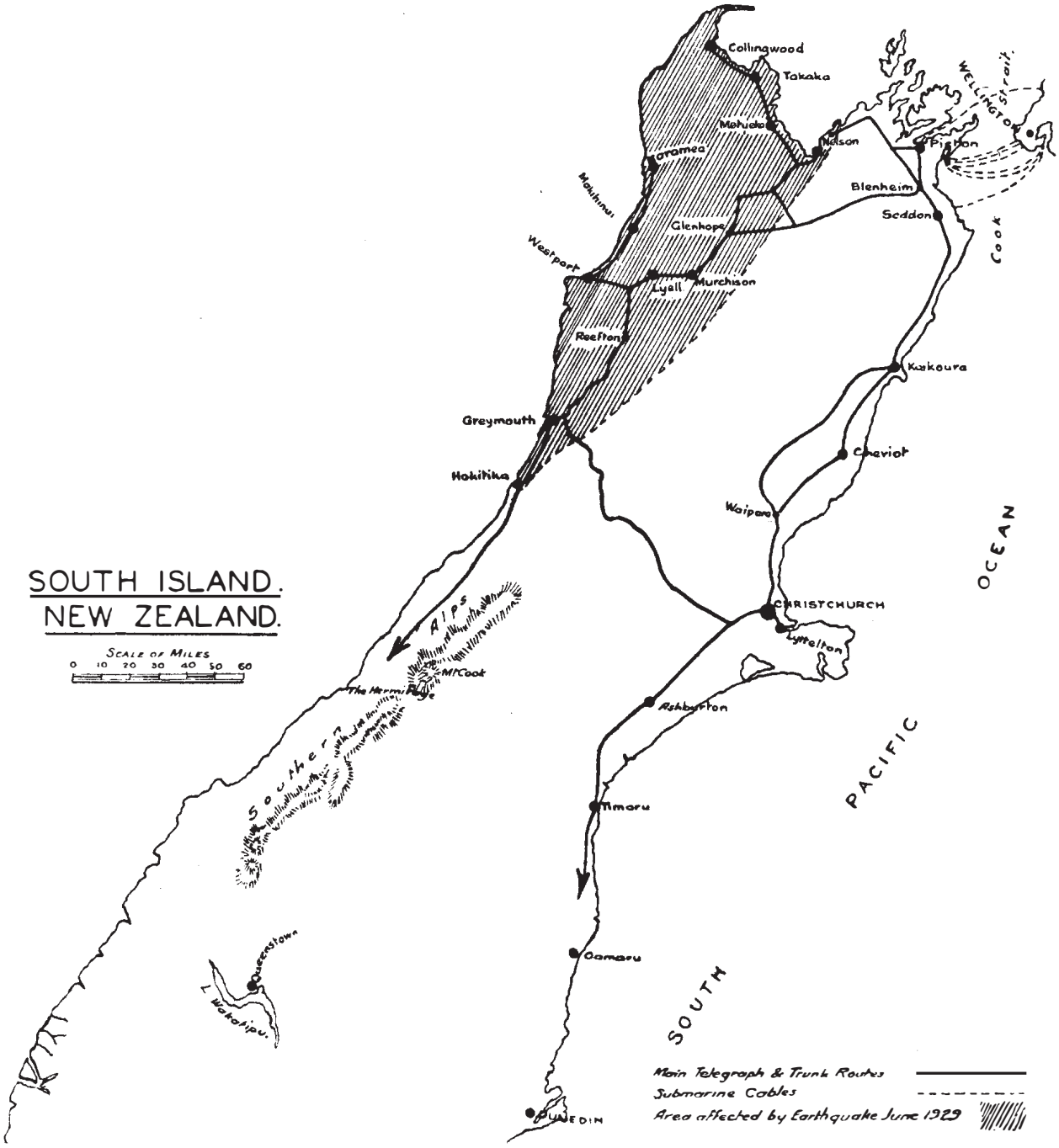
On the 17th June, 1929, at approximately 10.17 a.m., the whole of New Zealand was shaken by an earthquake of particularly severe intensity. During the month that followed, over 500 shakes of varying intensities were recorded in the most affected areas. Preliminary investigations indicated that the epicentre of the disturbance had its origin in the Murchison District, situated in the north-western portion of the South Island. In this area the earthquake was of the maximum intensity on the Rossi-Forel scale. Roadways, bridges, buildings and land suffered considerable damage, while the topography of the countryside was extensively altered.

It was fortunate that the maximum intensity of the earth movement occurred in a thinly populated area. Twelve lives were lost as a direct result of the disturbance. Had the earthquake occurred at night time or affected a city such as Auckland, with its quarter of a million people, the loss of life would have been appalling. The disaster was in no way identical with volcanic action, and the maximum intensity was confined to a clearly indicated area, 50 miles long by 30 miles broad, west of Murchison.

The north-western portion of the South Island of New Zealand is mainly mountainous in character and not so adaptable to close settlement as other parts of the Dominion. The world-famed Buller River, which flows through this locality, was temporarily blocked by huge landslides from the mountain sides. The upper and lower gorge roads, so popular with tourists because of their scenic beauty, were similarly blocked by landslides. The lower road was cleared for traffic within a few days, but it will be many months before the upper road is restored to its original condition or even made reasonably passable.

Surveys in the Murchison area show that the upthrust of land reached a maximum of sixteen feet at some points, and that the decline in other places was nine feet. Geological experts describe the disturbance as one of the most extensive earth movements in modern history. A new area of land in the form of an island, sixty chains long and sixteen chains wide, was thrown up from the seabed near Mokihinui on the west coast to an average height of eighty feet.

The districts of Westport (population 8,000), Takaka (1,000), Karamea (600), Motueka (2,000), Nelson (17,000), and Greymouth (12,000) immediately surrounding Murchison were also



severely affected by the earthquake. Apart from these localities, no damage of any moment was suffered in other areas.

The Westport Post Office, a large and comparatively new brick building, containing the telephone exchange, was so extensively damaged as to necessitate its complete demolition at a later date. The Post Office tower, containing the town clock, fell into the main thoroughfare during the shake. Fortunately, the internal equipment of the telegraph office and telephone exchange was not seriously damaged, but had to be removed under hazardous and extremely trying conditions and reinstalled in an adjoining wooden building.

No damage resulted to the internal equipment of other departmental buildings in the disturbed areas beyond the breaking of

FIG. 1.—MURCHISON. MATAKITAKI SLIP. A HUGE TREE REDUCED TO SPINTERS.

hundreds of primary battery jars. The electrolyte in the secondary battery cells at the Greymouth and Nelson B.M.S.B. telephone exchanges, the Blenheim W.E. rotary automatic telephone exchange, and the Seddon voice frequency and carrier current repeater station was observed to swing from side to side in the containers, but none of the liquid was lost. By far the greatest damage was suffered by telegraph and telephone outside plant, both underground and overhead. The Westport telephone exchange duct system was badly damaged by crushing. Several cases also occurred in other areas of damage to underground armoured telephone cables. A fissure which opened up across the roadway at Takaka broke the lead sheathing of one cable in half.

Overhead plant, however, was the most severely affected, and staffs, transport and material supplies were considerably taxed to meet the emergency. Telegraph and toll lines were interrupted over practically the whole of the northern half of the South Island. Thousands of contacts occurred on telephone subscribers' lines in the more affected areas.

The greatest damage occurred immediately north and south of Murchison over an area of about 30 miles and between Mokihinui and Karamea. In these sections long lengths of pole line were carried away by gigantic landslides accompanying the earthquake or caused by the incessant torrential rain which followed for twelve days. Road transport to Westport and Karamea was impossible and, to enable communication to be established until the overhead lines were restored, an aeroplane was utilised to carry radio operators and short-wave wireless plant from Christchurch to Westport and Karamea.

FIG. 2.—MURCHISON. HODGSON'S GROCERY STORES.

FIG. 3.—MURCHISON. MATAKITAKI BRIDGE AND APPROACH.

FIG. 4.—MATAKITAKI SLIP. VALLEY FILLED TO DEPTH OF 80 FEET. ONE HOUSE BURIED AND 4 PERSONS PERISHED. HOUSE IN FOREGROUND IS TOP STOREY OF ANOTHER HOUSE AFTER MOVING ½ MILE.

The trunk lines between Murchison and Inangahua Junction and between Westport and Karamea have not been restored at the time of writing owing to landslides carrying away the roads on both routes. It will be some considerable time before repairs can be effected, and it is quite possible that new road and telegraph routes will in some cases have to be surveyed.

Queer happenings to pole lines came under notice in several instances. North of Westport, a line of poles erected near the roadside was thrown over at an angle of 45 degrees, making it impossible for traffic to proceed along the road. South of Murchison, the roadway alongside the Buller River dropped bodily a number of feet, leaving the pole line standing. At Takaka a line of poles was turned round about 20 degrees, straining the wires to fiddle-string tightness on

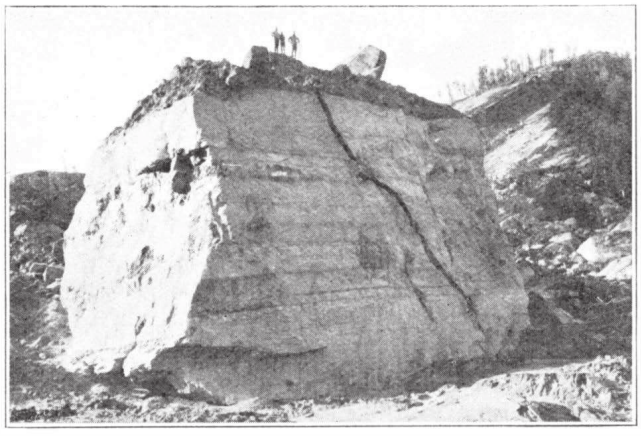


FIG. 5.—MURCHISON. BOULDER, 1000 TONS WEIGHT, COVERS HOUSE BELOW IT. THREE PERSONS PERISHED HERE. BOULDER CAME DOWN WITH MARIUS SLIP.

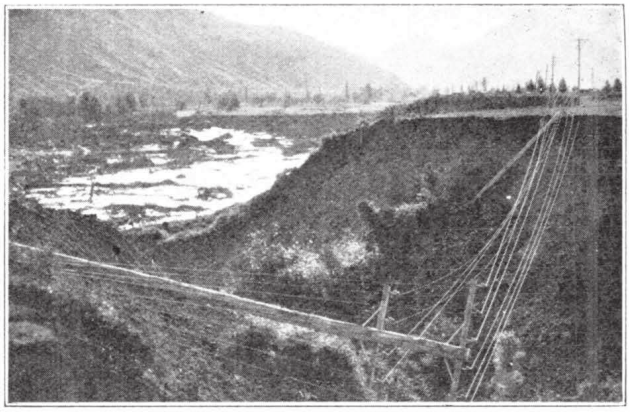


FIG. 6.—MURCHISON. POWER POLES AND LINES AFTER A FEW MINUTES DANCING.

one side of the arms, those on the other side resembling a clothes line. In the more severely affected area, poles were thrown out of alignment

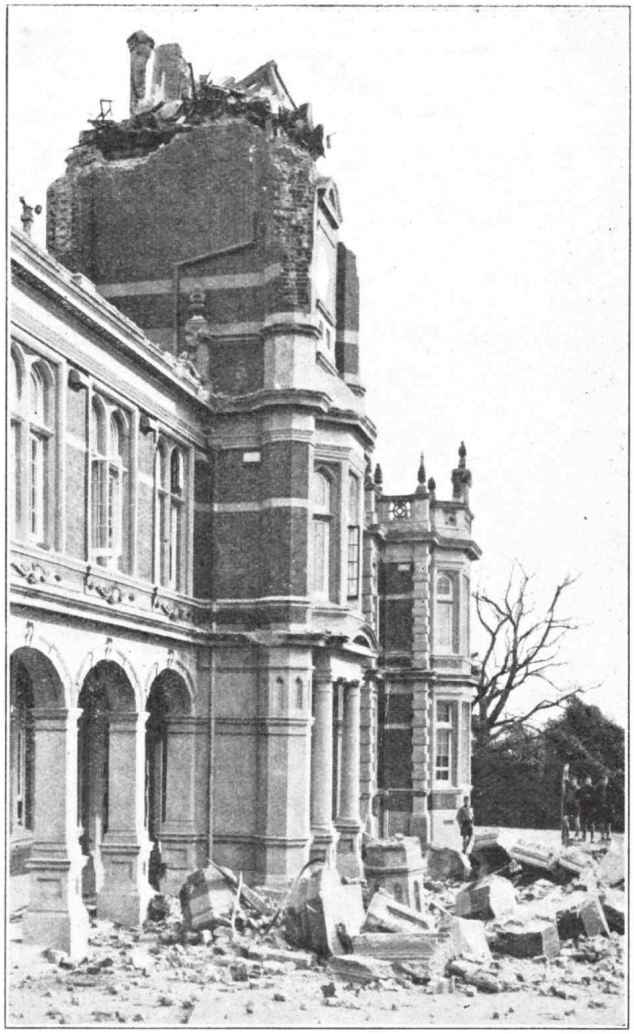


FIG. 7.—NELSON. REMAINS OF TOWER, BOYS' COLLEGE.

FIG. 8.—WESTPORT. POST AND TELEGRAPH OFFICE.

to one side or the other. Numerous cases occurred of angle poles shifting on the surface block while the heel block held. A number of Kaiwhaka (cedar) poles used for the power reticulation at Murchison were broken off at the ground line, completely wrecking the system. High tension and service lines fell across telegraph and telephone wires in all directions. Standard methods of protection and regulation crossings proved useless in such circumstances. Throughout the Murchison district, wires were found twisted together like messenger wire and had to be cut before they could be separated. In this area disconnections, due to the breaking of wires, were numerous. All drop leads on buildings at Murchison were broken.

During the week following the " big shake," communication between Nelson and Murchison was maintained with the utmost difficulty, owing to the recurring tremors, landslides and torrential rain. Linemen had a perilous and unenviable time restoring and maintaining communication, but their work greatly assisted in the arrangements for the evacuation of women and children and the transport of food supplies, etc., for the township and district. The early restoration of these services had a fine moral effect on the spirits of the townspeople.

FIG. 9.—WESTPORT. HARBOUR BOARD'S RAILWAY LINE.

FIG. 10.—REPAIRING BLENHEIM UG. CABLE.

Some idea of the magnitude of the damage to the overhead plant may be gained from the fact that it will take approximately two months to make permanent repairs in the Murchison district alone.

The use of telephone lines in the Murchison district by members of the Scientific and Research Department in connection with their sound-ranging apparatus was also an interesting feature. Electrolytic microphones were placed at points north, south, east and west of Murchison where the apparatus was located, the object being to determine the epicentre of the disturb-

FIG. 11.—KARAMEA. RUINED ROAD WITH FISSURE FILLED WITH WATER.

ance by time calculation from the well-known laws regarding the rate of travel of the main wave of an earthquake.

Several lessons are to be learned in New Zealand from the West Coast disaster. In cases of overhead line work no extraordinary precautions can be taken. Routes are invariably defined beforehand and the plant is at the mercy of nature's vagaries.

Secondary cells, but particularly the containers and stands, should be made of the strongest material. The electrolyte is always in danger of running over in cases of excessive swaying and should not be unnecessarily close to the top of the jars. The breaking of glass containers causes serious delay in replacement, and the plates are liable to buckle and deteriorate as a result of exposure to the air.

Exchange buildings should preferably be built of steel and ferro-concrete. Brick and stone structures in the affected areas were dangerously shaken by the earthquake. The placing of heavy automatic exchange switchgear above the ground floor needs careful consideration.

Where failure of the main water supplies are feared, an auxiliary tank or well should be made a part of the most important buildings. Fires are frequently known to complete the destructive work of an earthquake in congested areas. Fireproof structures to resist such an occurrence are required.

It is not known whether earth tremors giving rise to a wave motion that would cause damage to an underground system by working along its length are as destructive as sudden shocks, but it is apparent that greater attention requires to be given to structures of this character.

Where bridges are used to support duct systems or cables, care needs to be exercised to prevent breakages at the approaches, as many cases arose where the structure was lifted above or receded below the road level. The choice of a bridge of fireproof construction should be considered if alternative routes are available.

The crushing or collapse of conduits cannot be avoided in all cases, but consideration should

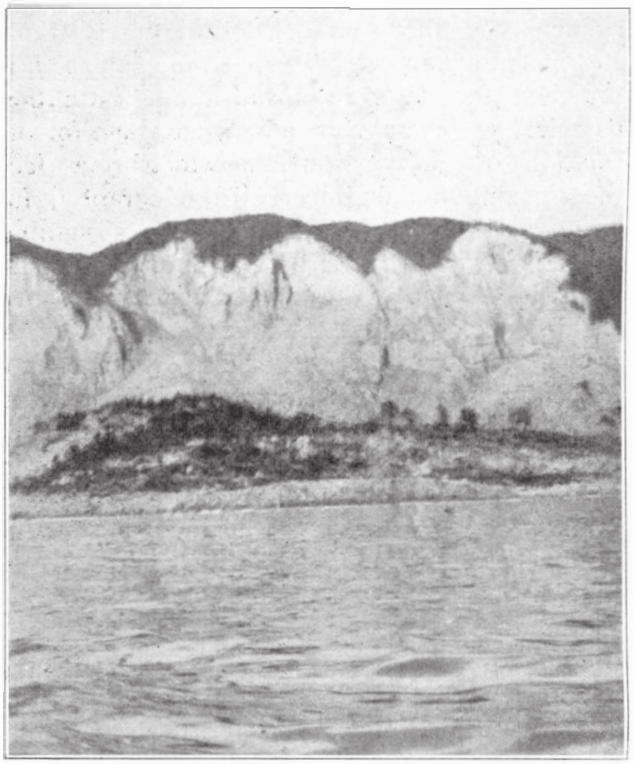


FIG. 12.—MOKIHINUI. SEA BOTTOM FORCED UP TO 80 FEET. DARK PATCHES ARE MARINE GROWTH AND SHELL FISH. LANDSLIDES EXPOSED WHITE CLIFFS.

be given to the class of material used and the method of jointing. Manholes and jointing chambers should be effectively drained to prevent excessive flooding.

It is extremely important that adequate supplies of emergency material and signalling apparatus should always be available and a local staff instructed in its installation and use.

As New Zealand is situated in the earthquake belt, a similar " shake " to that experienced at Murchison may affect one of the larger cities to the same extent as the well-known Japanese, Lisbon, San Francisco, etc., disasters. This probability cannot be disregarded by any branch of engineering, although most of the larger cities are fortunately not situated within the recognised earthquake belt circling the Pacific Ocean.

OPERATIONAL METHODS IN WIRE TRANSMISSION THEORY.

H. J. JOSEPHS.

THE object of making an analysis of a transmission problem, stated in a most general way, is to formulate as a function of the time, the current which flows in any part of the network in response to a suddenly applied voltage of arbitrary form. This means that the analysis is not limited to a discussion of steady-state oscillations only, but includes the study of transient phenomena following abrupt circuit changes. Whilst a knowledge of the symbolic steady-state analysis, involving the operator j, is sufficient for the solution of many important technical problems, it is quite inadequate for the solution of many problems which now face the transmission engineer. In telegraphy, for example, it is well known that the signalling speed is always limited by the transient effects, whilst in telephony, the transient effects form the limiting factor to the distance over which telephonic communication can be established. Consequently the analysis and design of transmission networks with special reference to their behaviour in the transient state and when subjected to overlapping transient effects are of considerable importance. There can be little doubt that the best method of attacking the more difficult transmission problems of telephony and telegraphy is the direct operational method invented by the late Mr. Oliver Heaviside. In the following article an endeavour has been made to review and discuss in simple language the application of operational methods to transmission problems.

It is now over forty years since Heaviside first began to publish his classical " Electrical Papers " and with them his operational methods of solving the descriptive differential equations of telephony and telegraphy. When tackling a transmission problem for the first time, Heaviside began by writing down the descriptive differential equations of the problem, which he could readily obtain from known physical laws. The next step lay in the solution of these differential equations and it was here that Heaviside found that the ordinary classical methods presented formidable mathematical difficulties and in many important cases broke down completely. This was the reason why he parted with academic methods and invented mathematical procedure of a radical and powerful sort. The problem that led Heaviside to his operational calculus was the determination of the building-up of the oscillations in an electrical network to which a voltage is suddenly applied. He obtained the set of simultaneous differential equations (1) to represent the general equations of electrical networks originally in a state of equilibrium when a voltage $\mathfrak{E}\, e^{pt}$ is suddenly applied. Thus,

$$\left.\begin{aligned} a_{11}i_1 + \ldots\ldots\ldots\ldots + a_{1n}i_n &= \mathfrak{E}\, e^{pt} \\ \ldots\ldots\ldots\

the problem is formulated by a partial differential equation.

Heaviside was concerned with the determination of the dependent variables $i_1, \ldots\ldots, i_n$, as functions of the time t, with the terminal condition that these variables are all zero for the independent variable $t \leqq 0$. In accordance with the theory of differential equations the complete solution of equations (1) must contain both particular and complementary solutions. The particular solutions gives the forced steady-state oscillations of the network which vary with time in accordance with the frequency of the impressed voltage and is obtained by putting $\frac{d}{dt} = j\omega$ throughout the general equations. The complementary solutions of equations (1) give the transient oscillations of the network which die away with increasing values of time t. The ordinary classical method of solution breaks down in the general case, because of the impossibility of locating the roots of the determinantal equation and determining integration constants from known terminal conditions.

Heaviside found that the general equations (1) may be made to depend upon the auxiliary equations (2), thus,

$$\begin{aligned} &Z_{11}(p) \cdot h_1 + \ldots\ldots\ldots + Z_{1n}(p) \cdot h_n = [1] \\ &\ldots\ldots\ldots

Hence, we may write

$$i_n = \frac{e^{j\omega t}}{Z(j\omega)} + \phi(t)$$

From equation (3) we get,

$$\frac{e^{j\omega t}}{Z(j\omega)} + \phi(t) = \frac{d}{dt} \cdot e^{j\omega t} \int_0^t h(\tau) \cdot e^{-j\omega\tau} \cdot d\tau$$

Putting $\int_0^t = \int_0^\infty - \int_t^\infty$ and making the indicated transformations, we get the functional identity,

$$h = \frac{1}{Z(p)} [1] = p \int_0^\infty h(t) \cdot e^{-pt} \cdot dt \quad \ldots.(5)$$

The above equation was first given by Heaviside in his " Electromagnetic Theory," Vol. III., where it is shown that the operational equation is the symbolic equivalent of infinite integral equation of the Laplace kind. Thus it can be seen that the problem of evaluating an operational equation has been reduced to the purely mathematical problem of solving the integral equation. The satisfactory solution of an infinite integral equation is, in the majority of cases, a very difficult matter. Fortunately, a large number of integrals of this type have been worked out and consequently the solution of operational equations can frequently be written down by inspection. When this is not the case, however, the procedure is to expand the operational equation in such a form that the individual terms can be made recognisable by transformation, as identical with known solutions. The integral theorem may be used to test the validity of a solution to an operational equation, and provides, through the work of mathematicians, the interpretation to certain operational equations which might not have been solved otherwise. Mr. J. R. Carson, of the American Telephone and Telegraph Company, makes the infinite integral theorem the central feature of his operational methods of analysis, and has, by its aid, ratified many of Heaviside's unestablished operational processes and deduced important criteria concerning the correct application of operational methods to transmission problems.

A simple example will illustrate the " go " of the integral theorem.

Let it be required to determine the current entering a smooth infinite line with distributed resistance R and capacity C per unit length. From the differential equations of the problem the operational equation is easily derived; we have,

$$I(t) = \sqrt{\frac{pc}{R}} \cdot [1]$$

Associating a known function in the integral theorem, we get,

$$\sqrt{\frac{C}{R}} \sqrt{p} \cdot [1] = \sqrt{\frac{C}{R}} \cdot p \cdot \int_0^\infty \frac{e^{-pt}}{\sqrt{\pi t}} \cdot dt \quad \ldots\ldots(6)$$

Hence,

$$I(t) = \sqrt{\frac{C}{R}} \cdot \frac{1}{\sqrt{\pi t}}$$

The above expression gives the current at any time t entering a smooth non-inductive line. Suppose now, that in addition to the distributed resistance R and capacity C, the line has distributed leakance G per unit length. The operational equation of the problem is now,

$$I(t) = \sqrt{\frac{pC + G}{R}} \cdot [1]$$

In order to solve this operational equation, make use of equation (6), by increasing p by λ throughout, where $\lambda = \frac{G}{C}$

Hence, we have,

$$\sqrt{\frac{C}{R}} \cdot \sqrt{p+\lambda} \cdot [1] = \sqrt{\frac{C}{R}} \left(1 + \frac{\lambda}{p}\right) \cdot p \cdot \int_0^\infty e^{-pt} \cdot \frac{e^{-\lambda t}}{\sqrt{\pi t}} \cdot dt$$

Thus,

$$I(t) = \sqrt{\frac{C}{R}} \left(1 + \lambda \int_0^t dt\right) \frac{e^{-\lambda t}}{\sqrt{\pi t}}$$

From the above equation it can be seen that the effect of the leakance G per unit length, is to attenuate the wave by the factor $e^{-\lambda t}$, and add a progressive integral component of the attenuated wave.

Another example illustrating the flexibility of the integral theorem will be given.

Suppose that it is required to determine the loading coil values for the loading of double-phantom telegraph circuits. A double-phantom circuit has a distributed series resistance R and inductance L per unit length and a distributed shunt capacity C per unit length. The distributed leakage conductance G, which in actual U/G cables is very small, may always be neglected when only quasi-distortionless high speed telegraphic transmission is being considered. If i denotes the current at any point l on the line, the descriptive differential equation for the current wave is,

$$\frac{\partial^2 i}{\partial l^2} = LC \frac{\partial^2 i}{\partial t^2} + RC \frac{\partial i}{\partial t} \quad \ldots\ldots(7)$$

The presence of L in the above equation introduces the phenomenon of true propagation with finite velocity, instead of the diffusion phenomenon which results when L is considered to be zero, as in an unloaded line. In order to investigate the factors influencing the formation of telegraphic signals, it is best to start with the direct current wave first, assuming that the line is terminated by its characteristic impedance.

A simple operational transformation of equation (7) yields,

$$i_1 = \frac{pC}{\gamma} \cdot e^{-\gamma l} \cdot [1]$$

where,

$$\gamma = \frac{1}{a} \sqrt{p^2 + 2\phi p}$$

$$a^2 = \frac{1}{LC}$$

$$\phi = \frac{R}{2L}$$

From the integral theorem, we get,

$$\sqrt{\frac{C}{L}} \cdot p \cdot \frac{e^{-\frac{l}{a}\sqrt{p^2+2\phi p}}}{\sqrt{p^2+2\phi p}} \cdot [1] = \sqrt{\frac{C}{L}} \cdot p \cdot \int_0^\infty e^{-pt} \cdot F(t) \cdot dt \quad \ldots\ldots(8)$$

The problem is thus reduced to the evaluation of the function $F(t)$. In order to make equation (8) agree with a known Bessel function, put $\sigma = \frac{l}{a}$ and $2\phi p = 1$, then rewriting equation (8), we get

$$\sqrt{\frac{C}{L}} \cdot \frac{e^{-\sigma\sqrt{p^2+1}}}{\sqrt{p^2+1}} \cdot [1] = \sqrt{\frac{C}{L}} \int_\sigma^\infty e^{-pt} \cdot J_0(\sqrt{t^2-\sigma^2})\, dt$$

where J_0 represents the Bessel function of order zero, which has zero value for $t < \sigma$ and the value $J_0(\sqrt{t^2-\sigma^2})$ for $t > \sigma$. Now assume that p increases to $p + d$, and we get after transformation,

$$\sqrt{\frac{C}{L}} \cdot \frac{e^{-\frac{l}{a}\sqrt{(p+d_1)^2+\sigma_1^2}}}{\sqrt{(p+d_1)^2+\sigma_1^2}} \cdot [1] = \sqrt{\frac{C}{L}} \int_{l/a}^\infty e^{-(p+d_1)t} \cdot J_0\left(\sigma_1 \sqrt{t_1^2 - \frac{l^2}{a^2}}\right) dt \quad \ldots(9)$$

where the arbitrary parameters are $d_1 = \frac{a}{l} \cdot d$ and $\sigma_1 = \frac{a}{l}\sigma$. Making equation (9) identical with the operational equation of the problem by putting, $d_1 = \phi$ and $\sigma_1 = j\phi$, we obtain

$$i = V \sqrt{\frac{C}{L}} \cdot e^{-\phi t} \cdot I_0\left(\phi \sqrt{t^2 - \frac{l^2}{a^2}}\right) \quad \ldots\ldots(10)$$

where I_0 is the Bessel function of imaginary argument and order zero. Also V represents the transmitting end voltage. Before equation (10) is applied to any particular case it is necessary to see that the number of loading coil sections n is great enough to make Cos $\left(\frac{\pi}{n}\right)$ practically equal to $\left(1 - \frac{\pi^2}{2n^2}\right)$ Also the right-hand side of equation (10) needs multiplying by the reflection coefficient K. Taking a particular case, we have, R = 11 ohms, C = 1.15×10^{-7} Farads, V = 50 volts, and l = 443 miles. The current that the receiving apparatus requires to work satisfactorily is 6 mA. From equation (10) the distributed inductance L per mile was found to be 0.2 Henry. This L value when multiplied by the distance in miles between the repeater stations gives the required loading coil inductance. In this particular case the calculated values were experimentally verified.

The chief feature of the above examples is the ease with which working formulæ has been derived, unfortunately, this advantage does not attend all the applications of the integral theorem, especially when it is applied to certain lumped networks. In many problems, excluding difficult types of transmission problems, it is found that, from the point of view of directness and simplicity, the direct operational method is preferable to the integral theorem. An example will make this limitation of the integral theorem clear.

Suppose that it is required to obtain a formula to represent the building-up of the sinusoidal currents in high-pass wave filters. For simplicity it will be assumed that the filter is terminated by its characteristic impedance, and that the series and shunt elements are non-dissipative. Let Z_1 represent the lumped series impedance and Z_2 the lumped shunt impedance. In operational notation, we have $Z_1 = \frac{1}{pc}$ where c is the series capacity, and $Z_2 = pL$ where L is the shunt inductance and p is the differential operator $\frac{d}{dt}$.

The operational equation for the direct wave h, in, say, the third section is easily obtained from an application of Kirchhoff's law. We have,

$$h = \sqrt{\frac{C}{L}} \cdot \frac{\left(\sqrt{1 + \left(\frac{\omega_c}{p}\right)^2} - \frac{\omega_c}{p}\right)^6}{\sqrt{1 + \left(\frac{\omega_c}{p}\right)^2}} \quad [1]$$

where

$$\omega_c = \frac{1}{2\sqrt{LC}}$$

Transforming the operational equation into a form in which Bessel series may be used and then expanding and identifying term by term by means of the integral theorem, we obtain the series,

$$h(t) = \sqrt{\frac{C}{L}}\left\{J_0(x) - 6\int_0^x [J_0(x) - J_1(x)]dx + 15\int_0^x\int_0^x [J_0(x) - 2J_1(x) + J_2(x)]dx^2 - 20\int_0^x\int_0^x\int_0^x [J_0(x) - 3J_1(x) + 3J_2(x)]dx^3 + \ldots\ldots\right\}$$

where $J_n(x)$ denotes the Bessel function of order n and argument $x = \omega_c t$. Now the e.m.f. $\hat{e}\sin\omega t$ is applied to the terminals at time $t = 0$, and consequently the required expression to give the building-up of the sinusoidal currents in the third section is obtained by an application of equation (3). It will be found that calculations made from the resulting series, whilst not actually impossible, are extremely difficult owing to the complicated nature of the mathematics involved. By means of Heaviside's expansion theorem or power series solutions, the transient oscillations in both high and low pass filters may be obtained with remarkable directness, even when the operational equation of the problem is complicated by dissipation and reflection. For the particular problem discussed above the expansion theorem yields the best form of solution because the characteristics of the dependent variable may be immediately determined by inspection.

These remarks are not intended to show that integral equation methods are not of great value. There can be little doubt that this method is one of the best for dealing with the very difficult problems of wire transmission theory. But there are certain problems, however, like the one discussed above, that can be solved more conveniently by other methods.

The integral theorem may be derived from the study of electrical networks in terms of the Fourier integral, and is, in fact, a general relationship resulting from Fourier analysis. This introduces the important fact that operational methods are the working tools of the classical Fourier method. This, however, was not the view of Heaviside, who appeared to have an even greater contempt for analytic functions than for other conventional mathematics. In the Fourier method of analysis everything is made to depend upon a known steady-state solution, a fact which seems to be the origin of considerable confusion and misinterpretation. Because the various schemes for solving the transient type of problem can be shown mathematically to depend upon a known steady-state solution, it must not be inferred that the one type of solution may be derived from the other merely by processes of ordinary A.C. mathematics. This, of course, is obvious from the mathematical consideration of the canonical equations (1). It will be interest-

ing, however, to illustrate the fallacy of this idea and to approach the operational method through the Fourier integral.

Consider the general case of an electrical network, originally in a state of equilibrium, to which an e.m.f. E(t), is applied at time t = o.

Let this applied e.m.f. be represented by the real part of the function $\dot{E}\,[1]\,e^{j\omega t}$.

Hence,

$$E(t) = E\,[1]\,e^{j\omega t}$$

In order to make an analysis of the building-up phenomena in the system we may commence with a study of the differential equation,

$$I(t) = \frac{\dot{E}\,[1]\,e^{j\omega t}}{Z(p)} \qquad \ldots\ldots(11)$$

where

I(t) = generated time function which represents the instantaneous value of the current in any section.

Z(p) = generating impedance function.

Rewriting equation (11) in terms of a Fourier integral we get,

$$I(t) = \frac{\dot{E}\,e^{j\omega t}}{2Z(p)}\left(1 + \frac{2}{\pi}\int_0^{\infty}\frac{\sin \omega t}{\omega}\,.\,d\omega\right) \ldots.(12)$$

The function Z(p) may be obtained from the auxiliary equations (2) and it can be seen that it is the points of discontinuity of this function which determine what process may be employed to evaluate equation (12). To evaluate this equation it is necessary to transform it into a contour integral. Making this transformation, we get,

$$I(t) = \frac{\dot{E}}{2\pi j}\oint\frac{e^{(p+j\omega)t}}{p\,.\,Z(p+j\omega)}\,.\,dp \ldots\ldots\ldots(13)$$

For $t <$ o the contour will enclose no poles and consequently the value of I(t) will be zero as it should be. For $t >$ o, however, the contour will enclose all the poles of the generating impedance function, which includes a steady-state pole at the origin which is included in the contour by surrounding the origin by a small semicircle. The path of integration may now, in accordance with the theory of residues, be deformed into small circles about each of the poles, and the sum of these residues will give the transient response of the network. The general problem is thus reduced to the evaluation of a contour integral. Now, for network problems, the function Z(p) has only a finite number of poles, all different from each other and from zero. Also all these poles are of the first order and lie on the left-hand side of the axis of imaginaries. In this case we have,

$$Z(p) = \frac{D(p)}{M(p)}$$

where D(p) and M(p) are polynomials in p; D(p) being of a higher order than M(p). A direct algebraic transformation of Z(p) gives,

$$Z(p) = \sum_{n=1}^{n=m}\frac{M(p_n)}{(p - p_n)D'(p_n)}$$

This enables us to evaluate the residues at the poles of the functional equation (13), and we get

$$I(t) = \frac{\dot{E}\,e^{j\omega t}}{Z(p)_{p=j\omega}} + \dot{E}\sum_{n=1}^{n=m}\frac{e^{p_n t}}{(p_n - j\omega)\,\dfrac{\partial Z(p)}{\partial p}_{p=p_n}} \qquad \ldots\ldots(14)$$

where p_1, p_2 . . . p_n are the roots of the equation Z(p) = o.

The first right-hand term of equation (14), is the steady-state A.C. component, whilst the summation term gives the transient oscillations.

Now, in general,

$$Z(p)_{p=j\omega} = R + jX$$

where R is the resistance component and X the reaction component of the impedance. Taking the real part of equation (14), we get,

$$I(t) = \frac{\dot{E}}{\sqrt{R^2+X^2}}\,\mathrm{Cos}\,(\omega t - \phi) + \dot{E}\sum_{n=1}^{n=m}\frac{p_n e^{p_n t}}{(p_n^2+\omega^2)\,\dfrac{\partial Z(p)}{\partial p}_{p=p_n}} \qquad \ldots\ldots(15)$$

If now the mathematics of ordinary A.C. theory are to be sufficient to solve the transient type of circuit problem, the following conditions must be fulfilled, namely: (*a*) the steady-state term must be zero at time t = o, and (*b*) the steady state term must be equal to

$$-\dot{E}\sum_{1}^{m}\frac{p_n}{(p_n^2+\omega^2)Z'(p)_{p=p_n}}$$

It can be seen at once, from equation (15), that both the necessary conditions are not fulfilled and consequently the mathematics of steady-state A.C. theory is insufficient for the solution of the transient type of circuit problem. It should be noted that the so called " Transient method " of circuit analysis is really a " Steady-state summation method." This fact may be readily verified by putting $\omega = 0$ and $\hat{E} = 1$, in the general equation (14), when we get.

$$h(t) = \frac{1}{Z(0)} + \sum_{n=1}^{n=m} \frac{e^{p_n t}}{p_n \left.\frac{\partial Z(p)}{\partial p}\right|_{p=p_m}} \quad \ldots\ldots\ldots(16)$$

which is the famous Heaviside expansion theorem derived from standard steady - state equations through the Fourier integral. From an expansion theorem solution it is generally possible to deduce by inspection the characteristics of the dependent variable without numerical calculation, an advantage not possessed by a series solution. The chief disadvantage of the expansion theorem solution lies in the fact that the location of the roots of $Z(p) = 0$ may be very difficult, and in some cases, even impossible. When dealing with transmission lines it is found that the roots of $Z(p)$ are infinite in number and consequently the difficulty involving in calculating from the expansion theorem would not justify its use. These remarks, however, do not apply to the non-inductive telegraph cable. For this case the expansion theorem solution is probably the simplest and most easily computed form of solution, and is, in fact, much easier to use than the A.C. steady-state method that has been developed for dealing with the telegraph cable. This A.C. method will now be briefly discussed.

In equation (12) put

$$\frac{1}{Z(p)} = \frac{1}{Z(j\omega)} = a(\omega) + jb(\omega)$$

and obtain

$$I(t) = \frac{Ea(0)}{2} + \frac{E}{\pi}\int_0^\infty \frac{a(\omega)}{\omega} \sin \omega t \, . \, d\omega + \frac{E}{\pi}\int_0^\infty \frac{b(\omega)}{\omega} \cos \omega t \, . \, d\omega \quad \ldots\ldots\ldots(17)$$

which is Milnor's A.C. method. In equation (17) the first term is of zero frequency and the integral terms contain components of all frequencies.

A very simple example will illustrate the limitations of the A.C. method.

Let it be required to derive an expression to represent the building-up of the current in a coil of inductance L and resistance R in response to a direct voltage E.

We have

$$\frac{E}{Z(j\omega)} = E \, . \, \frac{R - j\omega L}{R^2 + \omega^2 L^2}$$

and

$$I(t) = \frac{E}{2R} + \frac{E}{\pi}\int_0^\infty \frac{R \sin \omega t \, .}{\omega R^2 + \omega^3 L^2} \, . \, d\omega - \frac{E}{\pi}\int_0^\infty \frac{L \cos \omega t}{R^2 + \omega^2 L^2} \, . \, d\omega \quad \ldots\ldots\ldots(18)$$

The evaluation of infinite integrals of this type presents formidable mathematical difficulties, even in relatively simple cases. The infinite integrals of equation (18), have been evaluated by Bierens de Haan, and are given in " Nouvelles Tables D'Integrales Définies," page 252. From these solutions we get the well-known equation

$$I(t) = \frac{E}{R}\left(1 - e^{-Rt/L}\right) \quad \ldots\ldots\ldots(19)$$

For dealing with the problems of telegraphy and telephony, with the exception of the long telegraph cable in which the frequency range varies from zero to about 1.6 times the operating frequency, the A.C. method outlined above is practically useless, and will remain useless, until some device is invented for rapidly evaluating infinite integrals of the required type. It is interesting to note the remarkable ease with which the expansion theorem yields the above result.

We have $Z(p) = R + pL$

$$\therefore \quad Z'(p) = L$$

and $$p_1 = -\frac{R}{L}$$

Substituting in equation (16) we immediately obtain equation (19). Equation (17) illustrates a fact pointed out by Heaviside many years ago,

namely, that the transient behaviour of a network may be expressed mathematically in terms of its A.C. steady-state performance and is completely determined by the behaviour of the generating impedance function along the axis of imaginaries. This fact, however, must not lead to underestimating the complexity involved in actually constructing solutions for particular problems. Thus, A.C. methods lead us back to the consideration of the auxiliary equations (2) and the Heaviside operational equation (4). One of Heaviside's most difficult problems was the finding of practical ways of interpreting operational equations and he devoted the first two volumes of his " Electromagnetic Theory " to their solution. In his researches Heaviside made no pretence to rigorous formulation and only allowed physical and vectorial ideas to guide his mathematics to important results. One of his methods was to obtain the explicit solution of a number of problems by classical methods and then compare them directly with their operational equations. Thus he was led to attach a definite meaning to his operators which significance he would apply to those problems in which the classical methods failed him.

Heaviside usually evaluated his operational equations by expanding them in series and applying them term by term to the unit function [1]. Heaviside found that if the right-hand side of the operational equation be expanded in inverse powers of p, thus,

$$h = \left(C_0 + \frac{C_1}{p} + \frac{C_2}{p^2} + \ldots\ldots + \frac{C_n}{p^n} \right) [1] \quad \ldots\ldots(20)$$

then the operational expansion is converted into an explicit convergent power series solution by replacing $\frac{C_n}{p^n}$ [1] by $\frac{C_n t^n}{\lfloor n}$ throughout.

obtaining

$$h(t) = C_0 + C_1 t + \frac{C_2 t^2}{\lfloor 2} + \ldots\ldots + \frac{C_n t^n}{\lfloor n} \quad \ldots\ldots(21)$$

where the C's are constants.

It should be noted that the above method does not involve the determination of the roots of an equation and is particularly useful in discussions in which a knowledge of the first current surge is sufficient. In many practical problems it is found that the evaluation of the coefficients C_1, $C_2 \ldots C_n$ may be very laborious and that the slow convergence of the series makes the numerical evaluation rather tedious. In technical problems the best form of solution is one which enables us to infer the characteristics of the dependent variable without detailed calculation, and in this respect the Heaviside expansions leave much to be desired. When a power series solution of a problem exists it will be found to be far superior in its simplicity to any other form of solution. This method of expansion in power series is applicable to practically all problems which involve only lumped constants. There are, however, an important class of problems arising in connection with wire transmission theory where a direct power series solution does not exist. As an example of the use of the Heaviside power series expansion, consider the simple case of the first current surge in, say, the third section of a low pass filter. The operational equation of the problem, neglecting the disturbing effects of dissipation and reflection, is readily obtained.

We have

$$h = \sqrt{\frac{C}{L}} \cdot \left(\frac{\omega_c}{p} \right)^7 . F_1(p) . F_2(p) . [1]$$

where the factors

$$F_1(p) = \frac{1}{\sqrt{1 + \left(\frac{\omega_c}{p} \right)^2}}$$

$$F_2(p) = \left(1 + \sqrt{1 - \left(\frac{\omega_c}{p} \right)^2} \right)^{-6}$$

and ω_c denotes $\frac{2}{\sqrt{LC}}$

Each factor must now be expanded by the binomial theorem. After this, the two resulting series must be multiplied together, from which the required power series solution can be immediately obtained. A very serious inherent disadvantage which is attached to power series expansions is that unless the series can be recognised and summed its slow convergence makes the numerical work very laborious.

For the class of problems where a power series solution does not exist Heaviside found that if the operational equation can be transformed into

$$h = F(p) . \sqrt{p} . [1]$$

where F(p) is some function of p which admits of a power series expansion in p, so that the operational equation may be written as

$$h = (C_0 + C_1 p + C_2 p^2 + \ldots\ldots + C_n p^n)\sqrt{p}\,[1]$$

where the C's are constants and n is integral, then a divergent and asymptotic series is obtained by replacing $\sqrt{p}\,[1]$ by $\frac{1}{\sqrt{\pi t}}$ and p^n by $\frac{d^n}{dt^n}$.

Heaviside also found that if the operational equation of a problem can be transformed into the form

$$h = (C_0 + C_1 p + C_2 p^2 + \ldots\ldots + C_n p^n)\,[1] + \sqrt{p}\,(d_0 + d_1 p + d_2 p^2 + \ldots\ldots + d_n p^n)\,[1]$$

then, in general, a solution divergent and asymptotic may be obtained by discarding the first expansion entirely, except for the first constant term C_0, and making the same substitutions as before.

Heaviside in his " Electromagnetic Theory," Vol. II., gave no information or criteria for the correct application of his divergent expansion methods. Consequently he left the theory of the divergent solution of operational equations in a rather unsatisfactory condition. It should be noted, however, that when an asymptotic expansion of a transmission problem exists, the Heaviside method will find the solution with incomparable ease and directness. A simple example will make this clear. Let it be required to derive a formula for the current entering a loaded line. The operational equation of the problem, neglecting the distributed leakance G, is obtained from the differential equations and may be written in the form

$$h = \sqrt{\frac{C}{L}} \cdot \sqrt{\frac{p}{2\phi}} \cdot \frac{1}{\sqrt{1 + \frac{p}{2\phi}}} \cdot [1]$$

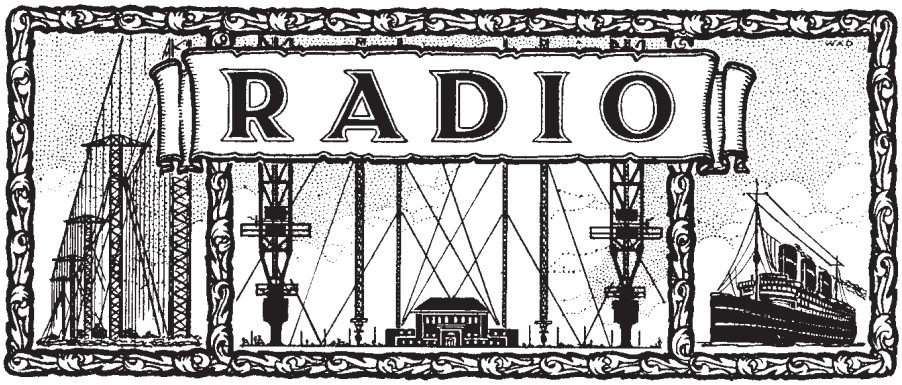
where $\phi = \frac{R}{2L}$

Expanding the denominator by the binomial theorem and replacing $\sqrt{p}\,[1]$ by $\frac{1}{\sqrt{\pi t}}$ and p^n by $\frac{d^n}{dt^n}$, we obtain the asymptotic expansion of the function,

$$h(t) = \sqrt{\frac{C}{L}} \cdot e^{-\phi t} \cdot I_0(\phi t)$$

The asymptotic expansion of this function is usually derived by very difficult and intricate processes, a fact which may be verified by consulting Watson's " Theory of Bessel Functions." The supreme ease and simplicity of the Heaviside method is remarkable.

It may seem strange that wire transmission analysis that deals entirely with real variables finds it necessary to use the theory of the complex variable to rigidly establish some of its fundamental laws. This is, however, due to the fact that the analysis of transmission networks is really the study of their behaviour when subjected to discontinuities and the introduction of the theory of discontinuous functions into wire transmission theory is not merely a matter of elegance but one of practical necessity.



PORTISHEAD SHORT WAVE TRANSMITTER.

A. J. Gill, B.Sc., M.I.E.E., M.I.R.E., and A. G. McDonald, A.C.G.I., B.Sc., A.M.I.C.E.

General.—In order to give facilities for handling ship and shore traffic on short wave-lengths, an experimental short wave transmitter was brought into operation at Devizes in 1927. Prior to the use of wave-lengths of the order of 17-40 meters, long range communication was effected through the medium wave transmitters at Devizes, which were afterwards transferred to Portishead. These transmitters had a working range of approximately 2000 miles. Telegrams for ships outside this range are transmitted from Rugby, but in this case under normal circumstances no reply from the ship to the effect that the telegram had been received is possible. In the case of ships fitted with short wave transmitters acknowledgment is possible and it was found that during some part of the 24 hours, usually between the hours of 1500 to 0400, communication could be effected over very long ranges.

On closing down Devizes Radio Station and transferring its services to Portishead opportunity was taken to rebuild the short wave transmitter and change the aerial system.

Power Supply.—The power supply of the transmitter installed at Portishead consists of a synchronous motor-generator set driven from an outside three-phase A.C. supply, 416 volts, 50 cycles; the D.C. output of the motor-generator drives a motor-alternator and a motor-generator. The output of the motor-alternator, 400 volts, 300 cycles, single-phase, supplies through the transformer the main H.T. feed, and the output of the motor-generator, 20-30 volts, is used for heating the filament of the oscillator valve.

The main power for the Devizes transmitter was obtained from a 30 B.H.P. crude oil engine coupled to a D.C. generator. The A.C. and D.C. supplies for the transmitter were obtained from a D.C.-driven motor-alternator and motor-generator. The power supply at Portishead is A.C. and in the design of the new equipment for Portishead two alternative power supplies were possible:—

(1) New A.C. motor-driven D.C. generator for the filament supply and a new high tension transformer using the 50 cycle mains.

(2) Provision of new motor-generator set, the output from which would be suitable for driving the existing motor-alternators and motor-generators and using the existing high tension transformer.

The latter course was chosen, as the frequency of the existing alternators was 300 cycles per second, which would therefore give a better note with less smoothing equipment than a 50 cycle supply; also it was considered that the rotating armatures of the main motor-generator and the motor-alternator driven from it would tend to act as buffers and damp out any fluctuation of the

mains voltage due to the keying load of the long wave transmitters. This proved in practice to be the case and no trace of variation of the alternator voltage on a steady load could be observed at times when considerable variation of the mains voltage was evident.

The alternators were wound with an extra field winding designed to give constant output voltage under load and thus compensate for the fall in voltage due to the regulation of the alternator. The current supplied for the extra field winding was obtained by leading the negative high tension return of the oscillator from the centre tap of the main high tension transformer to the alternator and then back to the earthing point on the oscillator filament. This necessitated a switching system so that the central rectifier could be connected to either of the alternators and then to either of the oscillators in use.

The compensation due to the keying load is thus automatic and since a diverter is fitted the current in the extra field can be adjusted so that the alternator voltage remains sensibly constant under varying loads.

Normal working figures for the installation are:—

	Alternator. Voltage.	*Plate Voltage.*	
Alternator level compounded	400	8700	Off load.
	400	6550	On load.
	360	5440	On load with extra winding not in use.
Alternator over-compounded	400	8700	Off load.
	425	7000	On load.

The difference between the on and off load plate voltages when level compounded is, of course, the difference between the peak voltage and working voltage of the rectifier.

Although a smaller variation of the plate voltage is possible by over-compounding, it is not used because under certain conditions—mainly when the transmitter is being retuned—a reaction effect is experienced. The increase in alternator volts increases the high tension volts and feed current and this in turn increases still further the alternator volts, so that on a long "mark" the supplies build up continuously until the overload trips.

The subsidiary switchboard handling the supplies to the transmitter is shown in Fig. 1. The board is of the dead-front type and consists

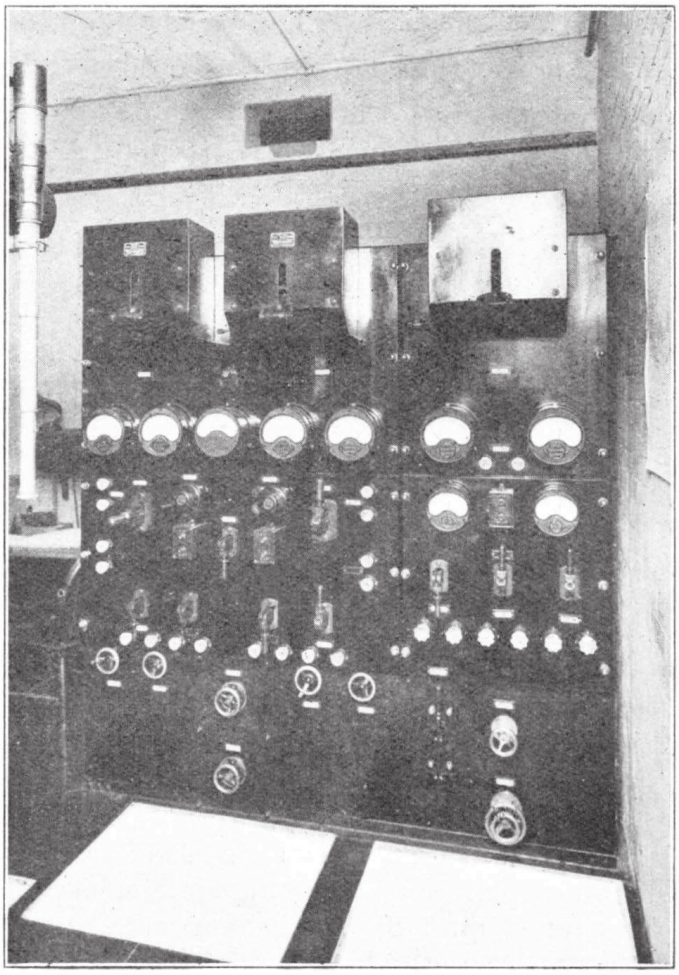


FIG. 1.—SUBSIDIARY SWITCHBOARD.

of an A.C. panel on the left and a D.C. panel for filament supplies in the night. Means are provided for synchronising and paralleling both the 300 ~ alternators if desired.

Transmitter.—The transmitter, Fig. 2, con-

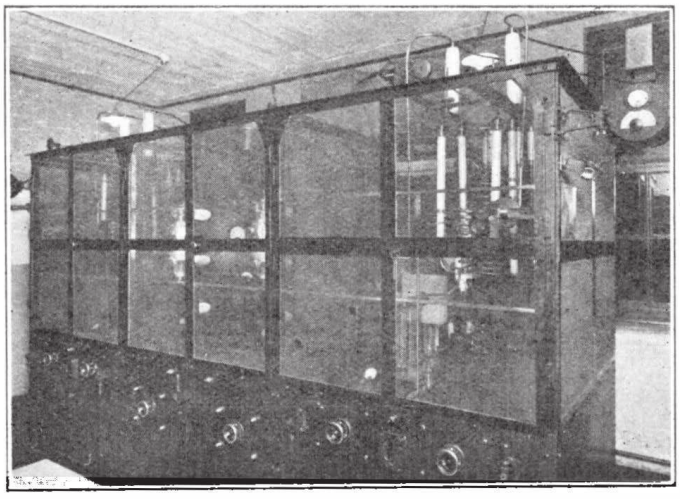


FIG. 2.—THE TRANSMITTER.

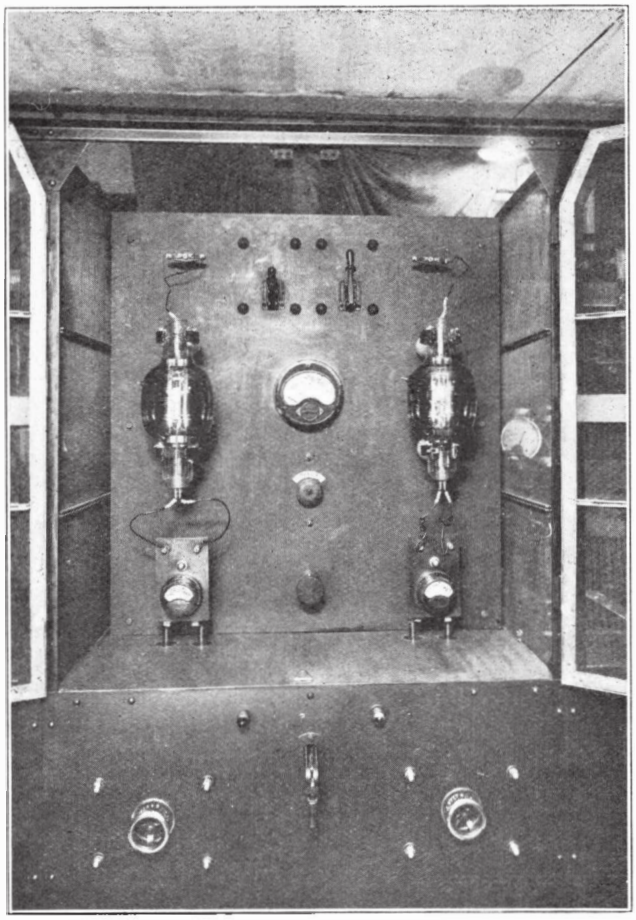


FIG 3.—BI-PHASE THERMIONIC RECTIFIER.

sists of a brass framework divided into three screened compartments. The middle compartment contains the rectifier, that on the left the 26.59 metre transmitter and that on the right the 36.54 metre transmitter. The high tension supply for the transmitter is obtained from a bi-phase thermionic rectifier (Fig. 3) fed from a motor-alternator set. The normal high tension voltage is 7000. Two glass rectifier valves, each capable of dissipating 1500 watts, are used and, under the present conditions of running, lives of 7000 hours have been obtained. Power is switched on and off from the transmitter by a contactor system and interlocked with it are overload releases, safety switches on all enclosures in which high voltage equipment is situated and an alarm and shut-down circuit should the air blast cooling the oscillator valves fail.

Two complete and separate oscillators are used for the two wave-lengths of the transmitter and these are fed from one central rectifier. Switching arrangements permit the earthing of one of the oscillator enclosures while the other is in use so that maintenance duties may be carried out. The filaments of the rectifier valves are heated from the main 50 cycle A.C. supply, and since they are not working up to saturation the voltage variations of the mains have no effect on the high tension supply. The rectifier panel is sheet steel, porcelain and paxolin insulators being used where necessary.

Oscillator System.—Two separate oscillator units, one tuned to 36.54 meters (8210 Kc/s) and the other tuned to 26.59 meters (11280 Kc/s) are used. All the condenser settings, coupling between coils, etc., remain untouched and the change in wave-length can therefore be made in 20 seconds. Fig. **4** shows the details of the 26.59 meter oscillator and Fig. **5** shows a general circuit diagram. The type of oscillating circuit used is one which has been developed by the

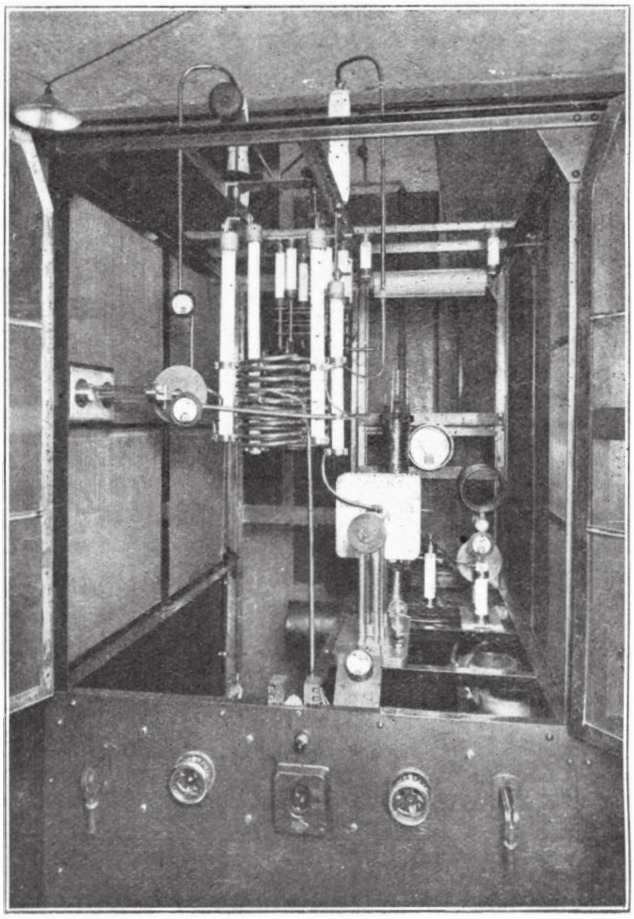


FIG. 4.—26.59 METER OSCILLATOR.

Post Office and has been found to be very stable and suitable for single valve transmitters.

A single silica valve having a maximum dissipation of $3\frac{1}{2}$ kilo-watts is used as the oscillator valve and has proved satisfactory, lives of over 5000 hours being obtained.

The high tension supply after rectification has two 0.25 microfarad smoothing condensers connected across it. The supply is therefore only partially smoothed and the resulting emission is interrupted continuous waves. It has a characteristic note due to the remaining ripple which serves to help to identify the station, but can of course readily be heterodyned. A pure C.W. transmission was employed for a short time at Devizes and more smoothing was used initially at Portishead, but in tests with ships it was found that for a service of this character the operators had a strong preference for I.C.W. transmissions. The oscillator valve filaments are heated by direct current from a motor-generator set, across the terminals of which is floated a secondary battery, but for emergency use A.C. can readily be brought into operation. All tuning controls of the transmitter are external to the enclosure so that there is no danger of the operators incurring risks during tuning operations.

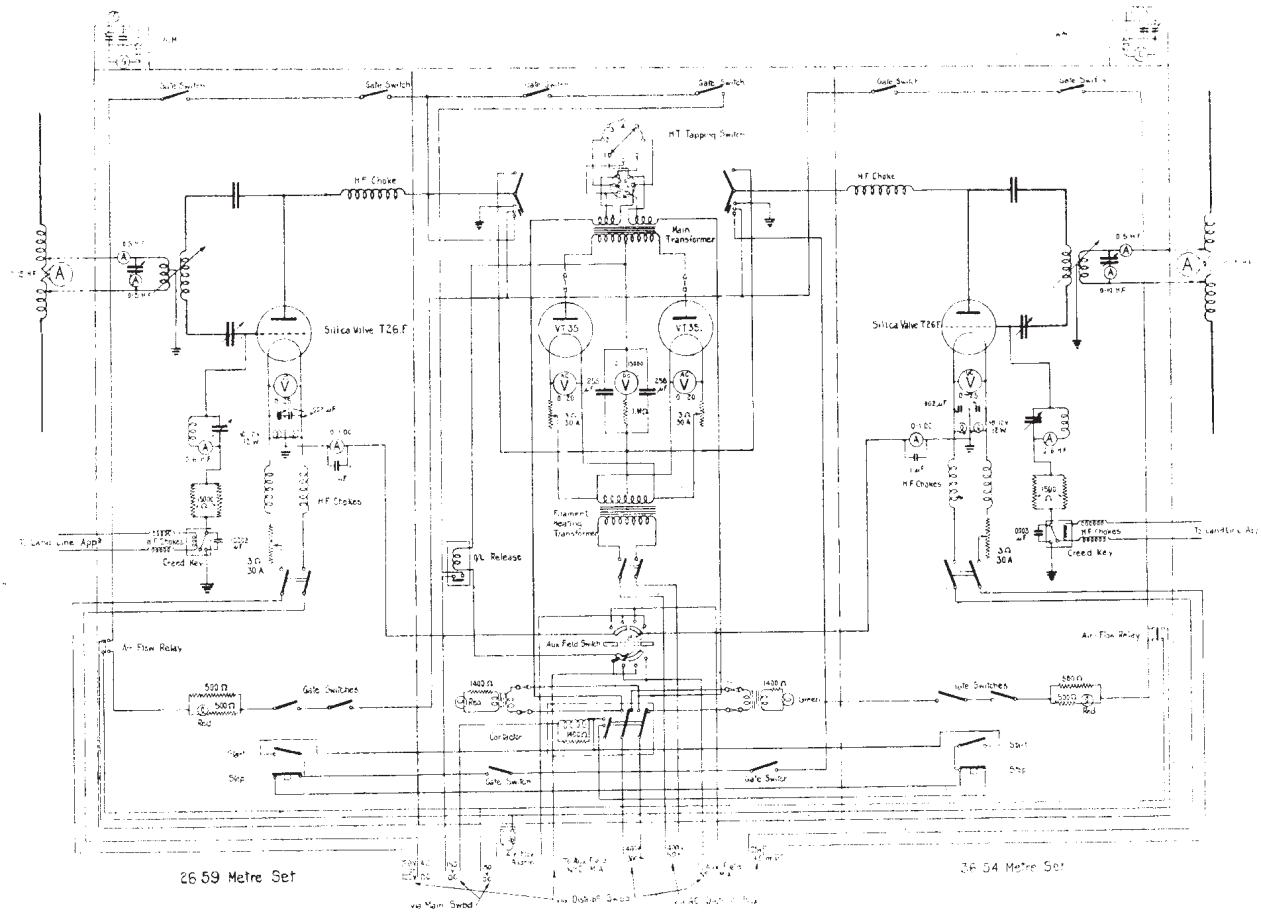


FIG. 5.—CIRCUIT DIAGRAM.

All the insulators are of porcelain and pyrex. No wooden frameworks or fittings are used. The transmitter is keyed by interrupting the grid circuit. There is thus no radiation on "space." The adjustment of the tuned grid circuit is such that no sparking at the key can be observed. During erection, tests were con-

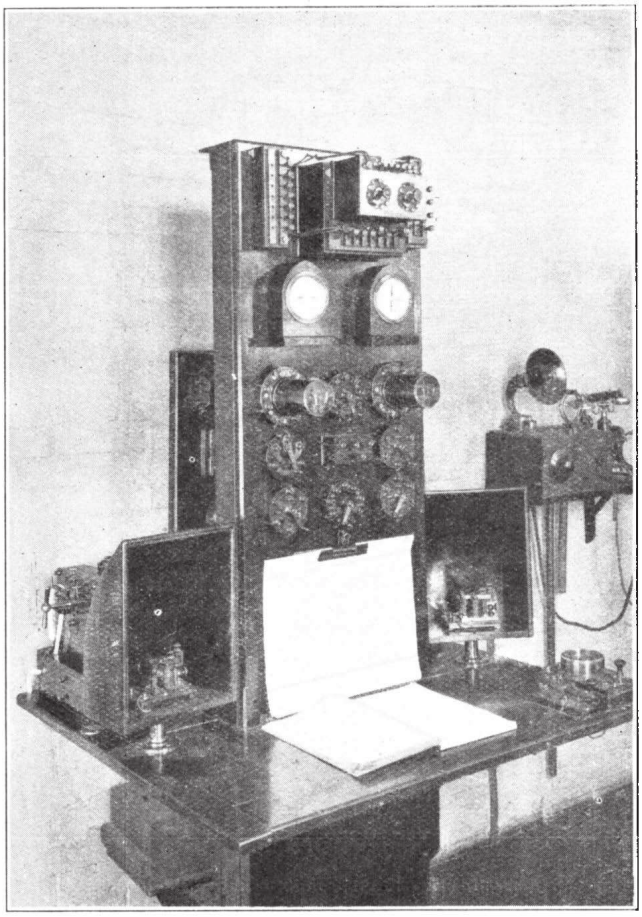


FIG. 6.—TELEGRAPH CIRCUIT APPARATUS.

ducted to ascertain whether or not the use of sheet steel round the bottom of the framework had any detrimental effect on the aerial current. With the coils in their present position no variation in aerial current with sheathing on or off was noted. The grid, anode and filament seals and the envelope of the silica valve are cooled by an air blast. Failure of the air supply is protected against by a relay trip circuit. Wave meters are permanently fitted to the top of each oscillator framework so that the wave length can be checked at frequent intervals.

Control.—Reception of ship's transmissions is carried out at Burnham Radio Station and control of Portishead transmitter is therefore effected from this station. Simplex telegraph working is used for this as a telephone circuit is available as a speaker between the two stations (Fig. 6). Control from the Central Radio Office, London, was also required and in this case the line is worked duplex. Switching arrangements are also provided so that the transmitter can be keyed locally. The transmitter is controlled by a Creed key operated by the telegraph signals. The machines for the power supplies, etc., are switched on in advance of the regular times of working so that all coils, resistances, etc., are warmed up to their normal working temperature, thus minimising possible slight changes in wave length.

Aerial System.—Separate aerial systems (Fig. 7) are used for each of the wave-lengths. In each case a half wave dipole consisting of a copper tube mounted on porcelain insulators and supported on a 70ft. wooden pole is used as an aerial. The aerial is fed at the centre by a transmission line. The impedance of the aerial and its coil was matched up to the surge impedance of the transmission line by varying the taps at which the transmission line joined the aerial coil. The transmission lines in each case consist of two 400-

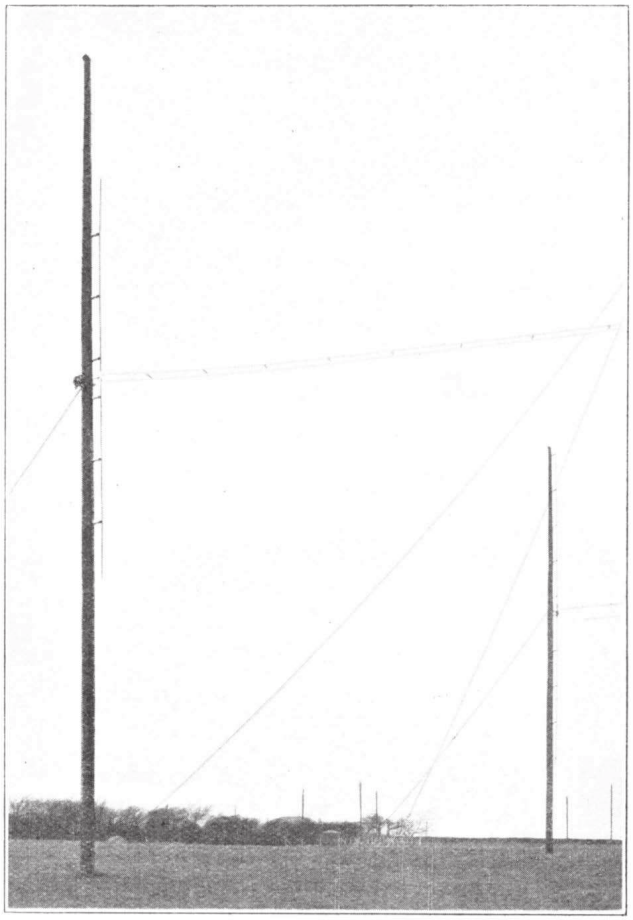


FIG. 7.—AERIAL SYSTEMS.

lb. copper wires, spaced 9″ apart and supported on line insulators on 36ft. poles. In the course of tests it was found that the sway of the transmission lines during stormy weather had a marked effect on the oscillator output, and accordingly the transmission lines were laced together with pyrex insulators. Slight flexibility at the point where the lead in enters the building is allowed, to avoid breaking the glass window.

The aerial ammeters are mounted on the poles and can be read by means of a telescope from the transmitting room.

Tests.—Normal working powers for the transmitter, using a Mullard silica valve T.26.F as oscillator are:—

Wavelength.	36.54 *metres.*	26.59 *metres.*
Main D.C. supply—volts	140	140
current—amps	62	64
A.C. Alternator Output—volts	416	400
amps	11.3	11.5
Plate Volts	7000	6800
Plate current—milliamps	500	500
Aerial current—amps ...	8.8	7.6
Transmission line current—amps	3	2½

The working range of the transmitter covers practically the whole of the world and ships are regularly worked at very long distances. A normal log of Burnham is as follows:—

RECORD OF SHORT WAVE SHIPS WORKED BY PORTISHEAD S.W. TRANSMITTER, CALL-SIGN GKT.

JAN. 11TH, 1930.

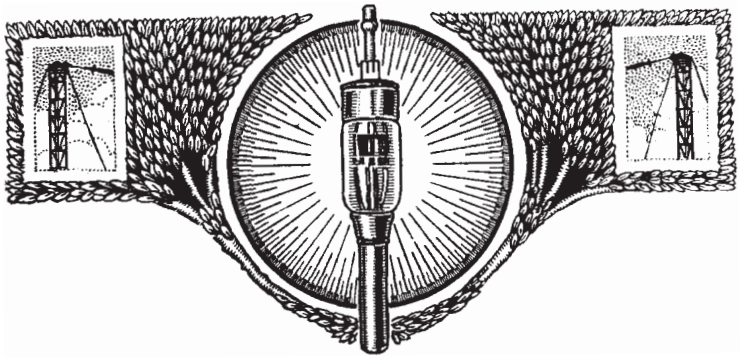
		Ships Wave.	*Position.*
0010	Saragossa VPNJ	35.5	Near South Pole.
0100	Guiliocesare IBWO	36	Pernambuco for Rio.
0112	Orania PGOB	36	Santos for M. Video.
0832	Southern Princess ZMGK	36	Ross Sea, 12,500 South.
1507	Aorangi GDVB	36	807 Miles S. Sydney.
1540	Vegoe LDHN	36	500 West Lands End.
1610	Yorkshire GDKC	36	Due Suez 0600/12th.
1645	Oxfordshire GLZF	36	Due Port Sudan 12th.
1817	Narkunda	36	Mediteranean.
1820	Arundel Castle GCZL	36	Due Durban 12th.
1855	Egero LDIQ	36	About 800 South.
1940	Kenilworth Castle GLVT	36	2,000 Miles South.
2130	Coronda VPNL	36	3,000 Miles South.
2136	Mazzini IBYO	36	At Port Sudan.
2204	Bremen DDAS	36	New York.
2216	Olympic GLSQ	36	New York.
2247	Duchess of York GSYN	36	St. John's N.B.
2254	Saragossa VPNJ	36	In Pack Ice S. Pole.
2319	Kenilworth Castle GLVT	36	See Above.
2022	Duchess of Richmond	36	St. John's N.B.
2035	Orontes GBXM	36	Red Sea.

JAN. 12TH, 1930.

Time.	*Ship and Call Sign.*	*Ships Wave.*	*Position.*
0011	Kenilworth Castle GLVT	36	2400 South.
0032	Carnarvon Castle GJSL	36	2200 South.
0034	Narkunda GCVB	36	Port Said.
0049	Thorshammer LCTJ	36	South Antarctic.
0105	Caronia GLRY	36	Havana.
0325	Saragossa VPNJ	36	Near South Pole.
0824	Southern Princess ZMGK	36	12,000 Miles South
0852	Caronia GLRY	36	Havana.
1103	Bremen DDAS	24.5	2,600 West.
1513	Aorangi GDVB	36	Off Auckland.
1535	Oronites GBXM	36	Red Sea.
1800	Oxfordshire GLZF	36	Leaving Port Sudan.
2147	Coronda VPNL	36	3,000 South.
2231	Southern King GJZT	36	3,200 South.
2250	Yorkshire GDKC	36	Suez.
2300	Olympic GLSQ	36	Near New York.

At the present time the " Discovery " in the South Polar Regions is communicated with every day. No skip distance has been observed on the 36 meter transmissions and ships quite close in can readily be communicated with. The 36 meter transmitter is used during darkness and partial darkness periods and is much more effective than the 26 meter. This latter wave is used for daylight transmissions and is not entirely satisfactory. Previously a wave-length of 17.81 meters was used, but many of the ships' receivers would not readily oscillate on this wave-length. The comparatively recent growth of ship traffic on short waves can be judged from the following totals of words transmitted and received through the Portishead transmitter and the Burnham receiving station. The totals are expressed as a percentage of the total traffic.

From Ships.		To Ships.	
Messages.	Words.	Messages.	Words.
1927.			
0.6%	0.6%	1.3%	1.2%
1928.			
12.2%	11%	15.5%	17%
1929.			
87.2%	88.4%	83.2%	81.8%



NOTES & COMMENTS

THE Lord President of the Council of the Department of Scientific and Industrial Research has had under consideration the appointment of a Chairman of the Radio Research Board of this Department in succession to Admiral of the Fleet the late Sir Henry Jackson, G.C.B., K.C.V.O., F.R.S.; and, on the recommendation of his Advisory Council, he has appointed Lieutenant Colonel A. G. Lee, O.B.E., M.C., Assistant Engineer-in-Chief, G.P.O., to be Chairman of this Board, of which he has been a member since August, 1928. Our heartiest congratulations are extended to Col. Lee on this important appointment which has been conferred upon a P.O. official for the first time. Col. Lee has also been appointed a Vice-President of the American Institution of Radio Engineers.

A fusion of manufacturing interests has been arranged between The Relay Automatic Telephone Company, Limited, and The Sterling Telephone & Electric Company, Limited.

The manufacturing facilities at Relay House, Streatham Hill, will be considerably augmented to deal with the dual output of these two Companies, which will manufacture Automatic Telephone apparatus and Manual Telephone apparatus respectively.

All enquiries in connection with the Sterling Company's products should now be addressed to:—

RELAY HOUSE,
STREATHAM HILL,
LONDON, S.W.2.

TELEPHONE DEVELOPMENT IN CANADA.

The Dominion Bureau of Statistics at Ottawa has forwarded to the High Commissioner of Canada in London its Report for 1928 on Telephone Statistics, from which it appears that the number of instruments in use increased by 6 per cent. during that year. The total number of telephones installed was 1,334,534, an average of 13.82 per hundred of the population. Canada comes second among the nations of the world in the utilisation of the telephone, her average being exceeded by that of the United States, which was 15.8 per hundred in 1927.

British Columbia led the Provinces of Canada with an average of 20.8 telephones per hundred of population, Ontario coming second with an average of 18.3 and Saskatchewan third with an average of 13.2, the other Provinces in order being Alberta with 12.3, Manitoba with 11.8, Quebec with 10.4, New Brunswick with 7.9, Nova Scotia with 7.8, and Prince Edward Island with 5.7 per hundred. The estimated number of telephone conversations during the year was 2,292,000,000 local calls and 36,177,000 long-distance calls.

Telephones in Canada are not operated by the Dominion Government, and there are no less than 2,447 telephone systems. Of these, five are owned by the Provincial Governments of Alberta, Saskatchewan, Manitoba and Ontario; 137 are municipal and 1,557 are co-operative; these being mostly in the Province of Saskatchewan. Private telephone systems numbered 161, many of these being transcontinental private

lines; and 93 telephone systems are operated by partnerships.

Telephone wire mileage is 3,982,867, pole line mileage totalling 207,566, including 4,546 miles of underground conduits.

One Company to spend $160,000,000 in five years.

The Bell Telephone Company of Canada proposes to spend $31,500,000 this year in the Provinces of Quebec and Ontario as part of its five-year programme comprising the installation of 250,000 new telephones, involving a gross outlay of $160,000,000.

INDUSTRIAL RESEARCH IN CANADA.

The High Commissioner of Canada in London has received from the Canadian Manufacturers' Association at Toronto a copy of the January, 1930, issue of its monthly journal " Industrial Canada " which is largely devoted to the question of research in Canada.

The journal in question contains articles by officials of the National Research Council at Ottawa, as well as one by the Chairman of the Ontario Research Foundation, and others describing industrial research in Alberta, Nova Scotia, New Brunswick, British Columbia, Prince Edward Island and Saskatchewan. It can be consulted at the Canadian Building, Trafalgar Square, London, S.W.1.

" WIRED WIRELESS " DEVELOPMENT IN NORTHERN ONTARIO.

The Bell Telephone Company of Canada is constructing in Ontario, at a cost of $1,500,000, a new line from Oshawa to Sudbury, *via* North Bay. The line, about 300 miles long, will be operated on the " wired wireless " principle, making it possible for eight persons to converse at one time over the same pair of wires, or for two people to talk and 40 people to be in communication on teletype or telegraph simultaneously.

Construction will be completed in a year from the beginning of operations, and the line will handle not only the increasing telephone business between Toronto and the northern Ontario mining districts, but will be a link in the Atlantic-Pacific system. On the completion of this transcontinental project, being brought into existence by co-operation between the Bell Telephone Company and the various telephone systems in the Maritime Provinces and western Canada, persons in Halifax will be able to talk to Vancouver over an all-Canadian route with perfect audibility.

FROM " THE TELEGRAPH AND TELEPHONE AGE " OF FEB. 1, 1930.

Harold Vivian, chief control operator of the Columbia Broadcasting Company, formed part of the circuit which enabled the radio audiences of fifty-nine stations in the United States and Canada to hear the speech of King George V. at 6 o'clock in the morning on January 21, at the opening of the Naval Conference in London. A few minutes before the King was to speak, a member of the control room staff of the Columbia Company tripped over a wire leading to the generator which energizes the Columbia network. Vivian examined the breakage. It would take at least twenty minutes, he realized, to make repairs. Meanwhile the King's speech would be over and thousands of radio listeners who had sat up late or arisen early to hear him would be disappointed. Vivian grasped the ends of the broken wires, one in either hand, to restore the circuit. The shocks of the 250-volt charge and the leakage of the current through his body to the floor shook his arms with spasms, but he held on until new wires could be connected. By that time his hands had been slightly burned and he was feeling the effects of the ordeal. As soon as the broadcast was finished he was sent home to bed. He had been through a tremendous nerve-racking experience, but the doctors said that he was not seriously hurt. The King's speech lasted six minutes. It was not preceded by any announcement. His voice was heard clearly, but none of the thousands of the Columbia's listeners was aware that save for Vivian's presence of mind and his pluck in clinging to the frayed ends of the broken wires their wait to hear the King would have been in vain.

EXTRACT FROM "THE ENGINEER," DATED 3RD JANUARY, 1930.

From their Tokyo Correspondent.

The World Engineering Congress in Japan.

"The telephone in its practical application is one of first-rate interest to every business man in Japan, where the price of the telephone placed in your house or offices is Yen 1200, say, £120 sterling. This price is fixed by the Government. The telephone situation here is so outrageous that foreign newcomers refuse to believe it, and quite naturally imagine that the old stagers are engaged in some regulation joke. The matter as it affects foreigners assumed a serious aspect quite recently when the Japan agent of a firm in Europe sent to headquarters a statement of establishment expenditure, which included the item Yen 2000 for telephone. He was threatened with legal proceedings, and it took quite a lot of explaining. In the boom years, 1917-21, the price of a telephone rose as high as Yen 4000. This extraordinary situation is created by that condition that causes all high prices—scarcity of the article in demand. It could be remedied within a year, but the interest of the "telephone broker," behind whom are banks who finance the broker, is of greater concern to the Government than the interest of the public. When some years ago, it appeared that an effort was to be made to end the situation and provide telephones for all who required them, the brokers rose in protest at the threat to their 'interests,' and had their way.

There are several ways of obtaining a telephone. One may be rented at a charge of from Yen 20 to Yen 30 per month, according to number and condition of the market. It is installed at a charge of about Yen 25—payable by renter—who must also pay the quarterly Government fee for use, amounting to Yen 16.50, and the sum of 3 Yen per call. To those in a hurry there is what is called 'quick installation,' whereby one who has deposited Yen 15 with the official telephone bureau and been promised an instrument within seven years, may obtain installation within six months by payment down of Yen 500 or thereabouts. Hundreds of thousands of ratepayers are on the books of the telephone bureaux in the different towns of the empire, each having paid a deposit of Yen 15—on which he receives no interest—who are patiently waiting, waiting. It has been said that a people has the Government it deserves!"

DR. M. MERKER.

We regret to record the death in Paris on June 28th last, of Dr. M. Merker.

Dr. Merker, who was born in Warsaw in 1886, joined the Bell Telephone Manufacturing Co. of Antwerp in November 1921, and remained there until December, 1928, when he was transferred to the Paris Laboratories.

Dr. Merker will be chiefly remembered in this country for his work on the application of the Theory of Probabilities to problems of Telephone Traffic. An article on this subject appeared in this Journal for April, 1924. But like others of his nationality, Dr. Merker was an accomplished linguist and other articles on the same subject will be found in the Technical Journals of both France and Germany.

Dr. Merker's death, at the early age of 43, is a serious blow to the technical side of Automatic Telephony.

POST OFFICE COMMERCIAL ACCOUNTS 1928-9.

Statement of Balances shown in the Telegraph and Telephone Income and Expenditure Accounts since 31st March, 1912.

Year.	Surplus or Deficit (after charging interest on Capital). Telegraph.	Telephone.
	£	£
1912-13	-1,175,347	303,343
1913-14	-1,211,742	239,111
1914-15	-1,232,955	- 111,018
1915-16	- 520,047	- 118,177
1916-17	- 529,639	201,729
1917-18	- 556,330	355,468
1918-19	- 685,139	- 36,261
1919-20	-2,636,183	-1,961,710
1920-21	-3,728,779	-4,721,970
1921-22	-3,032,246	- 559,132
1922-23	-1,696,836	939,009
1923-24	-1,270,925	1,596,917
1924-25	-1,645,525	463,006
1925-26	-1,299,214	550,830
1926-27	-1,340,112	283,375
1927-28	-1,380,829	107,391
1928-29	- 757,237	524,695

In commenting on the previous year's accounts we stated that the year now covered by these accounts would probably show better results, and this is borne out by the above figures.

As from 1st April, 1928, the Imperial Cable and Beam Wireless Telegraph Services were transferred to Imperial and International Communications Ltd. The Imperial Cable Service Account does not now appear and the Wireless Telegraph Service Account loses much of its importance. The cash receipts from Broadcasting licences amounted to £1,358,187, of which sum the B.B.C. received £887,616.

In the Telephone Service Income and Expenditure Account, the income for the year from rentals, call fees, etc., amounted to £20,348,722, an increase of 1½ millions over the previous year. The expenditure expanded by £1,036,975, the chief increases being £528,639 for depreciation and £341,040 in interest on capital, as would be expected from the larger plant, etc.

The total capital raised amounts to £120,239,166, but of this £35,137,337 has been redeemed. The Engineer-in-Chief and Controller of Stores certify for the proper condition of the plant and the engineering stores in stock respectively. The assets in the General Account Balance Sheet, including land and buildings, plant, engineering stores, sundry debtors for revenue and cash in hand amount to £133,025,748.

Holborn Gas Explosion.

As the result of negotiations between the P.O. and the Gas Light and Coke Co., it was agreed that each party should bear the cost of restoring its own damaged plant and share equally compensation to third parties. For the purposes of the Commercial Accounts, the cost of repair to the P.O. may reach £48,000, of which one-third has been allocated to renewals and two-thirds to maintenance, apportioned between telegraph and telephones on a mileage basis. A sum of £30,000 has been placed in reserve against compensation to third parties.

HEADQUARTERS NOTES.

The resignation of Mr. S. A. Pollock, Staff Engineer in charge of the Research Section, has led to two changes in the administration at Headquarters. Captain B. S. Cohen, who was formerly at Dollis Hill and who had been in charge of the N.T. Coy's laboratories before the transfer, has returned to the Research Section, changing over from the Test Section to Research. Mr. C. Robinson has been promoted to take Captain Cohen's place in charge of the Test Section. Mr. Robinson is well known to the staff generally by his contributions to the literature of the I.P.O.E.E. on the subject of Telephone Repeaters and it is not too much to say that the successful operation of the underground network is largely due to his work on repeaters and their associated transformers and balances. His services in this direction are widely recognised throughout the world, as he has read several papers before the C.C.I. meetings on the continent. As head of the Test Section, Mr. Robinson will still be closely associated with cable testing and it is understood he will hold a watching brief on the subjects of which he is an acknowledged authority.

EXCHANGE EQUIPMENT.

The following works have been completed:—

Exchange.	Type.	No. of Lines.
Brierley Hill	New Auto.	500
Davidson's Mains	,,	620
Dudley	,,	1220
Hillside, London	,,	2400
Mitcham	,,	1500
Stourbridge	,,	1020
Summertown	,,	600
Edinburgh Central	Auto Extn.	1460
Harrogate	,,	1700
Morningside, Edinburgh ...	,,	870
Murrayfield, Edinburgh ...	,,	650
Newington, Edinburgh ...	,,	660
Southampton	,,	410
Swansea	,,	1000
Bexhill	New Manual	1460
Farnborough (Kent)	,,	800
Herne Bay	,,	1250
Redhill	,,	600
Hitcham	,,	1270
Skegness	,,	620
Theydon Bois	,,	300
East Grinstead	Manual Extn	250
Ramsgate	,,	450
Sydenham	,,	2050
Airworks, Ltd.	P.A.B.X.	20
Bond Worth & Son	,,	30
Cheltenham Corporation ...	,,	30
Decca Gramophone	,,	30
Geo. Clark & Son	,,	30
Geo. Shaw & Co.	,,	30
Horlicks Malted Milk	,,	30
Mickley Coal	,,	20
Royal Sussex Hospital	,,	30
Wellsteads, Ltd.	,,	30

Orders have been placed for the following works:—

Exchange.	Type.	No. of Lines
Acorn, London	New Auto.	4400
Bristol Central	,,	5050
,, North	,,	2000
,, South	,,	1000
,, West	,,	3300
,, Bedminster	,,	875
,, Easton	,,	1500
,, Kingswood	,,	570
,, Stoke Bishop	,,	520
,, Westbury	,,	1100
,, Whitchurch		100
Cheriton		320
Folkstone	,,	2200
Hythe	,,	800
Kings Langley	,,	500
Lyminge	,,	160
Radlett	,,	760
Sandgate	,,	400
Watford	,,	3450
Bath	Auto Extn.	Obsn. Equipt.
Maida Vale	,,	Switching Plant.
Worthing	New Manual	3460
Altrincham	Manual Extn	960
Chester	,,	520
Guildford	,,	940
Perth	,,	360
Wembley	,,	1340
Bradbury Agnew	P.A.B.X.	40
Colgate Palmolive	,,	30
French & Sons	,,	30
Hollins & Co.	,,	30
Lewis Berger	,,	30
Royal Sussex Hospital	,,	30
Shell Mex (Plymouth)	,,	30

DISTRICT NOTES.

LONDON.

Exchange Lines and Extensions.

In December 31st, 1929, there were 383,356 direct exchange lines and 645,939 telephone stations in the London area. The increase during the quarter was 7,456 exchange lines and 12,456 stations.

The total number of private wire telephones in the London area is 16,640. An addition of 16,500 loop miles was made to the local line mileage, the total of which is now 1,283,150 loop miles.

New Auto. Exchange.

The "Primrose" Exchange, situated in the North West District of London, close to Regent's Park, was opened on the 15th February, 1930. The exchange equipment, which is of the "director" type, was manufactured and installed by the Automatic Telephone Manufacturing Company, Limited. Its installation occupied a period of about eleven months. At the transfer 4,026 subscribers' lines were cut in from the Primrose Manual Exchange and 700 new junctions were brought into use. The latter exchange has ceased to function temporarily, but will be re-conditioned and opened again in May, 1930, as "Cunningham," a manual exchange which will take the growth in the Abercorn area until the second unit of the new automatic Abercorn Exchange is built in 1934.

The new Primrose Automatic Exchange is

equipped for 6,900 lines. There are 57 ordinary units of 100 rotary line switches and final selectors, 52 "A" digit switches, 93 directors, 614 1st and 403 2nd numerical switches. The manual switching plant consists of 15 "A" positions and 6 "B" positions. The transfer operations, comprising the removal of heat coils at the closing exchange, the withdrawal of wooden wedges on the main frame at the new exchange and the simultaneous change over from coder call indicator to Strowger working at the automatic exchanges in the London network having direct junctions to the new Exchange, was effected in 120 seconds. A test of all circuits (subscribers' and junctions) was completed within three hours. Only 18 faults were discovered as a result of this test, representing 0.44% of the circuits transferred; there were no junction faults. The speed with which the transfer was carried out, the clean cut and orderly arrangements, the absence of any single adverse incident, together with the entirely satisfactory results obtained at the post transfer test, is very creditable to those who organised the arrangements.

Automatic Exchanges under Construction.

The equipment at the following automatic exchanges is well advanced:—

Amherst, Fairfield, Addiscombe, Livingstone, Macaulay, Shepherds Bush, Gladstone and Gulliver.

C.C.I. positions at Manual Exchanges.

The growth of automatic telephone traffic has necessitated the provision of additional C.C.I. positions at Finchley, Park, Clissold, Marylebone, East Hounslow, Paddington, Croydon and Putney.

New Manual Exchanges.

The following Manual Exchanges were opened on the dates mentioned:—

Springpark. Opened on January 1st on equipment previously used for Beckenham.

Redhill, No. 1 C.B. type equipped with 1400 lines. Opened on January 15th.

Theydon Bois, No. 10 C.B. type equipped with 300 lines. Opened on January 22nd.

New exchanges at Ingrebourne and Loughton are being equipped.

Corrosion of Cable Sheaths.

Cases of corrosion of cable sheaths are unfortunately not rare, but it is unusual to have faults of this type reported on adjacent cables while the ground is opened to clear specific trouble in one cable. The little demon who watches these matters usually arranges for the second trouble to occur after the repairs to the first cable have been completed and the job left. A case has recently occurred in the London District where trouble on three trunk cables were cleared at one point, although only one fault had been reported when the repairs were commenced.

When a partial breakdown on the Guildford cable was brought to notice, the position of the fault was located from Toll Test and the first opening of the cable was made at a point which proved to be 1.75 ohms from the seat of the trouble. Measurement of the distance from the first cut indicated that the fault was likely to be in a particular manhole in which the cable was very inaccessibly placed. It was desired, if possible, to avoid opening the joint at this point (A). A narrow slit was, therefore, made in the sleeve to enable access to be obtained to a pair for testing purposes. This pair was picked up at the next manhole (B) 51 yards distant and Varley and Murray tests were made to obtain a precise location of the fault.

The location of the fault as shown by the Varley test made from B was 3.75 yards from A, the location according to two Murray tests made from B was (1) at 2.28 yards from A, and (2) 0.2 yards from A. A further Murray test was then made from A by which the location of the fault was shown as 1.26 yards from A. The ground was excavated immediately outside the manhole and the conduits cut. No sign of damage to the cables was, however, found and the manhole wall was therefore broken into. At this point the cable was found to be very severely corroded and punctured in two places. Similar damage was also found to have been caused to the sheath of the Southampton cable. A breakdown on this cable was reported and localised by Toll Test and punctured in two places. Similar damage to the same neighbourhood during the time that the road-side localisation test was being made on the Guildford cable. The cable sheath of the Woking cable was also found to be badly corroded but not punctured. The faults on the

Guildford and Southampton cables were removed by the application of heat and carbon dioxide gas and the sheaths of the three cables were made good by patches.

Kiosks.

There are over 1,700 kiosks in the London District and the decoration of these receives close attention so that these conspicuous structures in the London streets may present a pleasing appearance. Arrangements are at present being made to carry out the work of re-decoration of 600 of the above number. The opportunity will be taken in the case of Kiosks No. 1 to introduce the new colour scheme, viz., Clipsham stone colour and Post Office red.

Telephone Arrangements for Naval Conference.

A brief reference was made in the last issue to the telephone arrangements for the Naval Conference and it might be well to state in more detail what these arrangements are, so that it may be seen what an important part the telephone plays in national and international matters to-day.

As is well known, the conference is being held in St. James' Palace. Over 90 telephones have been specially installed. In addition, it was necessary for the District staff to construct and fit 52 special cabinets for the use of Press representatives of various nations.

In these 52 cabinets are fitted 23 Private Wires to the various newspaper offices in the City and West End; 14 Multi Coin Boxes working on Regent for local and Toll calls; and 15 Telephones controlled by attendants for Trunk, Continental and Trans-Atlantic calls. Each Private Wire Cabinet is marked with the name of the newspaper to which it has been allotted, and the instruction cards and notices in the Multi Coin Box Cabinets are printed in English, French and German.

Two attendants' switchboards, controlling the 15 telephones mentioned above, with 15 Exchange lines on Gerrard and two direct lines to Trunk Records, are situated in the Guard Room behind a special counter provided for the Post Office. In this room there are also two Post Office Tele-printers working direct to the Central Telegraph Office and five Tele-printers owned by the chief Cable Companies. A Baudot telegraph set is also installed. Twenty-three extensions connected to a special Private Branch Exchange position in Gerrard Exchange have been installed in the various State Rooms used by the delegates, including three special cabinets in the Matted Hall for use by delegates who desire to make private calls. Two Private Wires to the Foreign Office also exist. The wiring of these extensions proved a matter of some difficulty owing to the necessity of carrying out all wiring and fixing without touching any of the valuable woodwork in the State Rooms. The problem of bringing the external leads in at each window was solved by raising the lower part and inserting a batten through which the leads were taken.

At the Ritz Hotel, two special $\frac{10 + 50}{65}$ switchboards were installed for the American Delegation, with 10 exchange lines and 75 extensions which were diverted from the main board. This necessitated the provision of a 100-pair cable from the basement to the fifth floor.

Similar arrangements were made at the Carlton Hotel for the French Delegation, where two $\frac{10 + 50}{65}$ boards with eight exchange lines and eighty extensions were fitted.

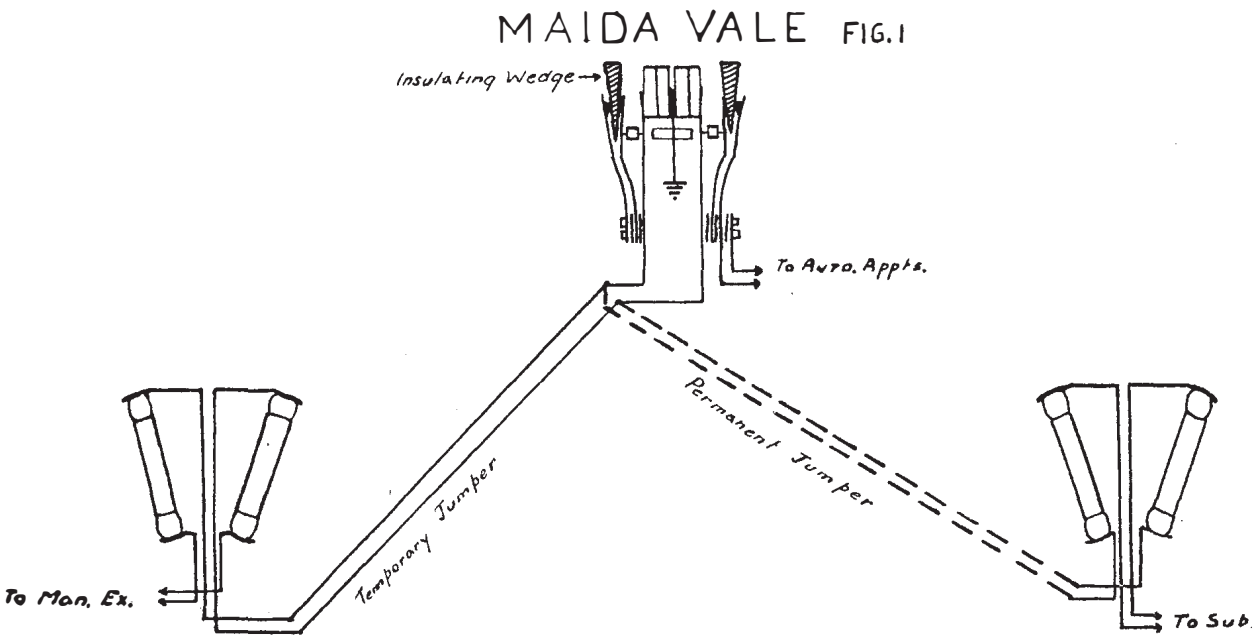
At Claridges Hotel a special $\frac{10 + 50}{65}$ board accommodating 8 exchange lines, and 30 extensions (24 of which were diverted from the hotel board) was installed for the Italian Delegation, while at 46, Grosvenor Square, an empty house which has been taken over by the Japanese Delegation, two $\frac{10 + 50}{65}$ switchboards with 10 exchange lines and 45 extensions were provided.

Exchange Transfers.

G. J. Gawthorne.

In connection with the transfer of Primrose Hill Exchange to the new automatic equipment, the external cabling scheme is such as to involve the diversion of about 75% of the subscribers' circuits *via* the new Main Distribution Frame so that tees to the new automatic equipment can be made on this frame and not externally. Similar procedure was adopted at the transfer

of Maida Vale and in that case it was found that the M.D.F. became very congested with jumper wires, which had to be cut away and recovered after the transfer. Some of these were very long and as there is a certain amount of risk in pulling out long jumpers, due to chafing, great care was necessary to prevent damage to the permanent jumpers.



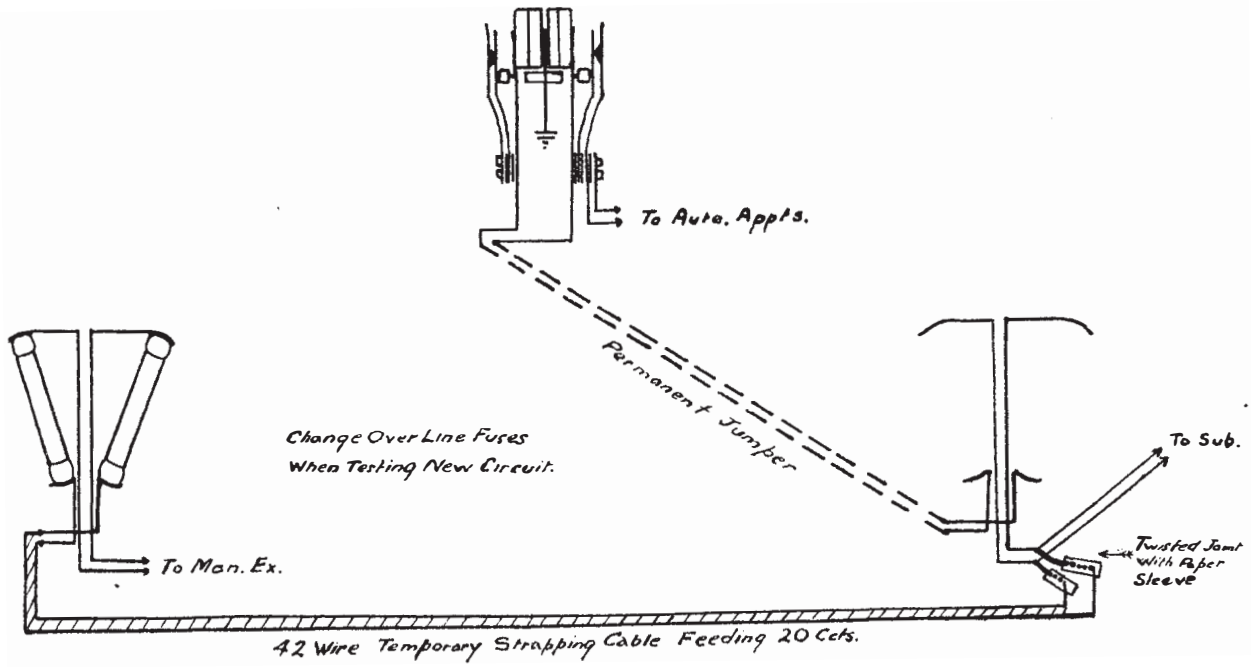
The method adopted at Maida Vale is shown in Fig. **1**, from which it will be seen that it was necessary to insert insulating wedges in the arresters on the automatic exchange side of the frame. As the diversions must take place some months prior to the actual transfer, these wedges become a continuous source of trouble to working circuits, owing to their being displaced accidentally by men working on the frame. It is also necessary to keep records of the temporary jumper and cable pairs and as the number of circuits concerned at Maida Vale was about 2000, this work occupied much time.

At Primrose Hill the number of circuits is about 3000, and in view of the experience at Maida Vale it was decided to adopt the method shown in Fig. **2**. By arrangement with the External Engineer, incoming cables from the subscribers have been connected by means of switchboard cable to the corresponding pair number in the outgoing external cable to the Manual Exchange. The switchboard cabling has been run on the under side of each shelf and is therefore quite clear of the jumper field. Odd lengths of old cable have been used, this being possible owing to a large quantity from old Edgware Exchange being available, but, even with new cable, switchboard cable is cheaper than 1 pair/12½ Flameproof. By strapping the two external cables through in this manner the diversion of the circuit is entirely in the hands of the External Engineer and diversions to the new cables can be made without the assistance of internal staff.

Running and terminating switchboard cables of 20 pairs is much faster than running 20 jumper wires; the internal men are therefore able to keep well ahead of the external, and the necessity for keeping a record is obviated. It will be noted in Fig. **2** that the switchboard cable is connected to a tag end which was not cut off when the main cable was terminated. The joint is insulated by means of a paper sleeve, and the main cable soldered connection is not interfered with in any way. The line fuses are also left out, which enables the permanent jumper to be run without interference with the working circuit after the diversion work is completed.

It is also unnecessary to insert insulating

PRIMROSE HILL FIG.2



wedges until all work on the M.D.F. is finished and everything ready for the dial speed and final testing to commence, when of course the subscribers' line fuses must be inserted. After the transfer the strap cables can be more easily cut away, and there is no risk of chafing permanent jumper wires when recovering.

The difference in the cost per 1000 circuits of the two schemes described, taking the average length of 10 yards per jumper, is as follows:—

Maida Vale	Labour	700 manhours
	Material	£41 13s. 4d.
Primrose Hill	Labour	300 manhours
	Material	£25 10s. 5d.
Saving on Primrose Hill:—		
	Labour	57%
	Material	38%

In addition to the advantages described above, the method adopted at Primrose Hill has the further advantage that the work of diversion is accelerated and the period during which circuits are liable to interruption by external operations is therefore reduced.

SCOTLAND WEST DISTRICT.

Underground Cabling Work by the aid of Mechanical Means and Improved Appliances.

J. D. Macleod.

The article by Mr. J. R. M. Elliott in the October, 1929, issue of the Journal has no doubt been read with a great deal of interest by all officers carrying out cabling work. Probably by this time the method used, or a modified form of it, has been tried in other Districts and it would be interesting to know the results obtained.

Shortly before the article appeared, a main cabling work of approximately 10 miles long was undertaken by the staff in Scotland West District. In this and subsequent cabling cases, mechanical aids of a simple nature were used for drawing in the cables and perhaps the following particulars of these aids and the results obtained will be of some interest.

As a motor winch was not available for drawing in the cable, consideration was given to the use of the best available local means and after tests and trials it was decided that the 3-ton

Albion motor lorry in use in the district was quite suitable for the purpose. Another special appliance used was a Grease-box designed by Mr. Aitken, Superintending Engineer, and constructed locally under the supervision of the Mechanic Shop Inspector. By this contrivance the cable is lubricated with the desired quantity of petroleum jelly in passing from the cable drum to the duct. The supply of grease is regulated by the weight 56 to 112 lb. in the weight box. The arrangement is simple and effective.

Particulars of the design of the Grease-box are shown in the foregoing Fig. 1. Outlet nozzles varying from one inch diameter upwards as required can be easily fitted to suit any particular size of cable. Fig. 2 shows the grease-box in position with the cable passing through the bed of petroleum jelly to the duct mouth. It may be mentioned that " Cable Reel Drum Jacks " were used instead of the old type of Drum Jacks. The former type was found to possess a decided advantage as compared with the latter type.

Fig. 3 shows the draw-rope hitched to the 3-ton motor vehicle with a rope guiding arrangement, made up of two 8-way arms fitted with two re-

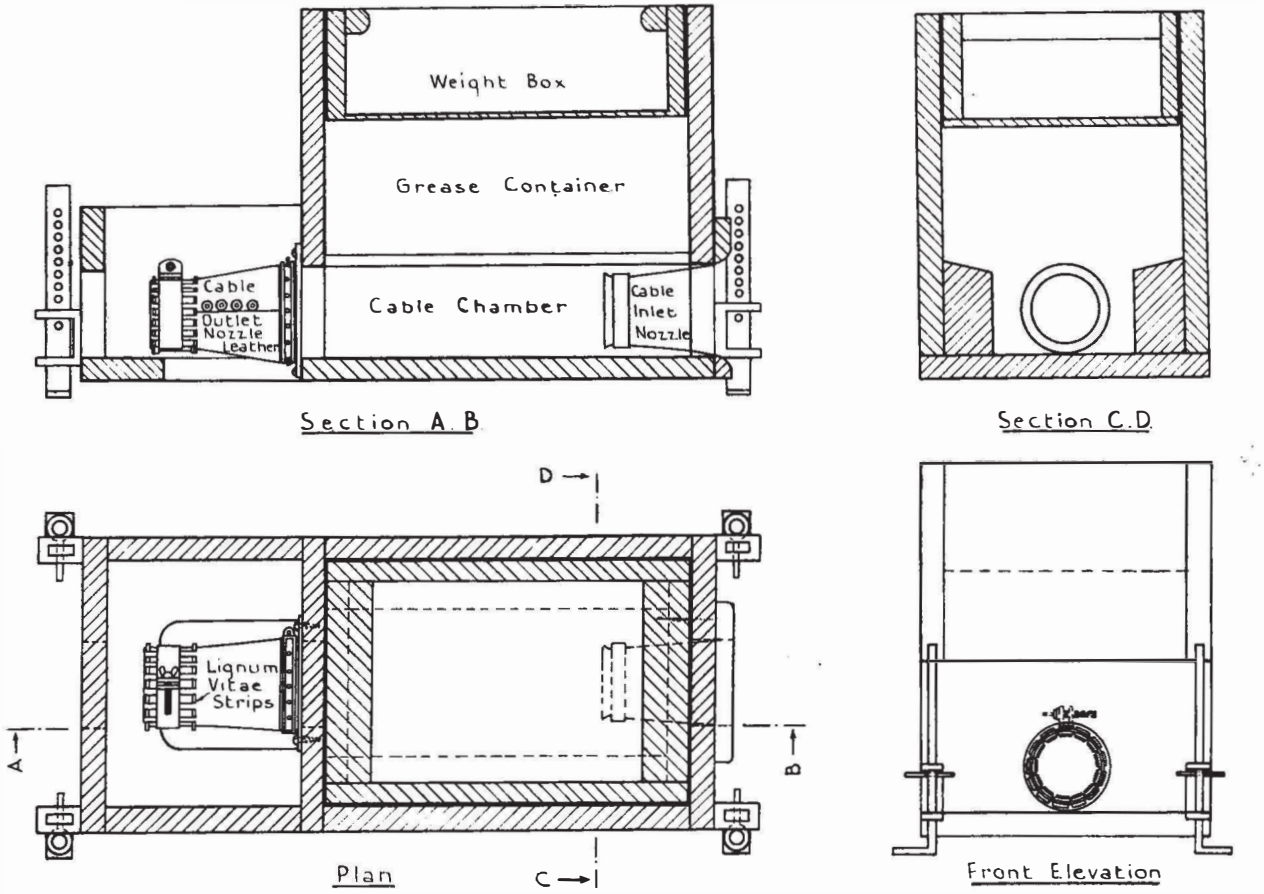


FIG. 1.—GREASE BOX DETAILS.

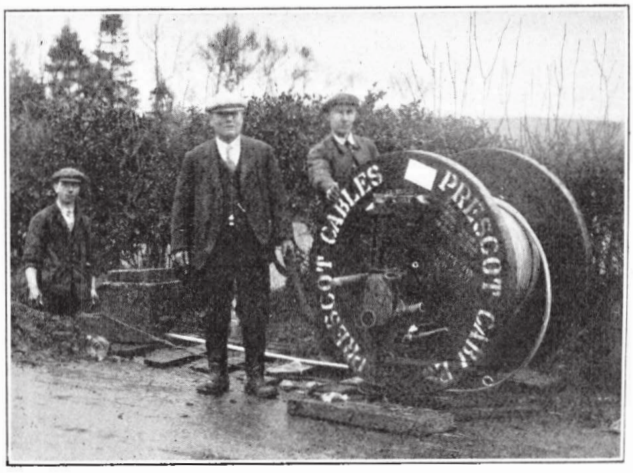


FIG. 2.—GREASE BOX IN POSITION.

FIG. 3.—DRAW-ROPE HITCHED TO LORRY.

volving pulleys, fixed in the jointing chamber. Two adjustable iron brackets are fitted at the lower pulley to permit the pulley being placed in line with the duct mouth. The arrangement is quite simple and effective and can be readily fixed in position.

The speeding up rendered by the aid of these appliances and the motor vehicle necessitate a definite organisation of the men employed in order to avoid overlapping and in order to make full use of the improvement derived from the mechanical aids. The organisation programme was given to the Inspector in charge of the work and also to the two Foremen, in schedule form (one Foreman was in charge of the cabling group and another Foreman was in charge of the men rodding duct, drawing in draw-ropes and opening joint holes in advance and also of the men filling in joint holes behind the cabling group). Without any previous instruction on the organisation arrangements it was interesting to watch the progress made with the work as the men benefited from each day's experience.

These brief notes will not permit full particulars of the organisation arrangement being stated, but the writer will be pleased to furnish full particulars to any officer desiring information on the point. The schedule arrangement should be altered to suit local requirements.

The following tabulated particulars show briefly the actual costs and the calculated savings by the foregoing arrangements, as compared with Provincial average costs, on the Greenock-Wemyss Bay Main Cable early in 1929, and within the last four months on the Coatbridge-Bathgate and the Wisham-Carluke-Lanark Main Cables:—

CASE I.—GREENOCK-WEMYSS BAY CABLE.
18,251 yards. Gp. III.
74 pr/70 P.C. 54 pr/70 M.T. 24 pr/70.

	Actual Manhours.	P.A. Rates.
Effective Manhours ... ... (Drawing in Cable).	1426	3650
Ineffective Manhours ..	627	1241
Total Manhours ..	2053	4891
Cost at Average Rate ...	£137 18 9	£328 12 3
Cost of 3-Ton Lorry ...	19 16 0	—
Estimated Cartage	—	34 13 0
Total	£157 14 9	£363 5 3
Nett Saving ...	£205 10 6	

CASE II.—COATBRIDGE-BATHGATE CABLE.
26719 yards. 54 pair/40 P.C. Quad.

	Actual Manhours.	P.A. Rates.
Effective Manhours ... ... (Drawing in Cable).	1247	5343
Ineffective Manhours ...	658	1817
Total Manhours ...	1905	7160
Cost at Average Rate ...	£128 19 8	£484 15 10
Cost of 3-Ton Lorry ...	24 0 0	—
Estimated Cartage	—	42 0 0
Total	£152 19 8	£526 15 10
Nett Saving ...	£373 16 2	

CASE III.—WISHAM-CARLUKE-LANARK CABLE.
17766 yards. P.C. Quad 40 lb. Gp. II.

	Actual Manhours.	P.A. Rates.
Effective Manhours ... ... (Drawing in Cable).	951¾	2008
Ineffective Manhours ...	350	686
Total Manhours ...	1301¾	2694
Cost at Average Rate ...	£88 2 9	£182 8 1
Cost of 3-Ton Lorry ...	13 0 0	—
Estimated Cartage	—	22 15 0
Total	£101 2 9	£205 3 1
Nett Saving ...	£103 0 4	

In Case I. approximately two miles of the route was in a busy industrial town and the remainder along a rural highway. The road is narrow at several points and has many bends.

In Case II. approximately 4½ miles of the route was through industrial towns and the remainder along a busy highway, but with very little cross traffic. It may be mentioned that in one short day—19th December to be correct—over three miles of cable was drawn in towards the end of the work and as the men benefited by previous days' experience.

In Case III. approximately 2½ miles of the route are in rural townships and 3 miles along a disused road. The remainder of the route is along a busy highway.

These hurried notes are put forward only as showing what can be done to speed up cabling work by the use of available local mechanical aids. The methods used in these cases are worthy of pursuit and the question of fitting suitable gear, for drawing in cables, on certain motor vehicles in use throughout the districts is thought worthy of consideration.

NORTH WALES DISTRICT.

Cases of damage to telephone poles caused by road vehicles are fairly common at the present time, but perhaps a rather unusual instance which occurred in the Stoke-on-Trent Section a few weeks ago may be of interest.

In this particular case, a Main Line pole (a 40-ft. Stout) carrying 21 important Trunk Circuits, was smashed clean in two by a motor-lorry without causing any interruption of service and no faults were reported as a result of the accident. The lorry, which was loaded with eight tons of rice in bags, was proceeding down a hill in the neighbourhood of Knypersley, North Staffordshire, at a speed obviously excessive having regard to the heavy load, the hill and the wet condition of the road at the time, when the application of the brakes caused it to skid sideways and crash broadside into the pole. Fortunately, the lorry came to rest over the place where the pole previously stood and the upper portion of the pole, with wires and arms undisturbed, was left firmly planted among the bags of rice on the lorry, practically over its original position.

The accompanying photograph shows the

state of affairs immediately after the accident and luckily no one was hurt. The curious character of the accident also facilitated repair work, as it was simply necessary to support the wires on extension arms and ladders while the broken pole was being taken down, and after the lorry had been pulled back on to the road, a new pole was erected in the original position without difficulty.

Dudley, together with Stourbridge, Brierley Hill and Cradley Heath Exchanges were changed over successfully at 2 p.m. on Saturday, the 8th February, 1930, to the new Strowger Auto Exchange equipment installed by Messrs. Siemens Brothers & Co., Limited. A total of 380 Junctions and Trunks and 2210 subscribers' lines were transferred.

The junction transfer arrangements were very complicated, necessitating the use of change-over strips at several points and included the diversion or ceasing of 123 direct junctions to sub-exchanges.

A large number of Trunk and Junction circuits

had to be diverted to Dudley, where the Manual Board for the area is situated.

Dudley was formerly an Automatic Exchange of the Standard Telephones & Cables Rotary Machine Switching type installed in 1916. The other three exchanges changed over were of the Magneto type.

At the invitation of Lieut.-Col. Brain (Postmaster-Surveyor, Birmingham) nearly three hundred representative people attended an interesting inauguration ceremony in Dudley on Friday, the 11th instant, when the Mayor of Dudley dialled the first call from the Town Hall. The Mayor of Stourbridge also dialled the first call from the Town Hall to Stourbridge. The Mayors, Col. Brain and Mr. R. A. Weaver (Superintending Engineer) made appropriate speeches, and afterwards the guests were entertained to tea in the Town Hall. The visitors then made a tour of inspection of the new Dudley Automatic Exchange accompanied by members of the Engineering Staff as guides.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS: CENTRE NOTES.

LONDON CENTRE.

The third meeting was held on December 10th, when Mr. J. C. Dallow read a paper on "Rural Automatic Exchanges." Lantern slides, and the demonstration of a working Rural Automatic Exchange Unit helped the audience to appreciate one more stage in the development of the Telephone Service. An interesting discussion followed to which Mr. Dallow ably replied.

At the fourth meeting on January 14th, Mr. J. N. Hill read a paper entitled "Critical Methods of Investigation as applied to the study of Telephone Areas and Plant Layout." Lantern slides helped to elucidate many of the problems, and the subsequent discussion and Mr. Hill's masterly reply to the many critical questions, held the interest of the audience. The paper is undoubtedly a valuable addition to the literature of Plant Layout.

The fifth meeting was held before a large gathering on February 11th, when Capt. A. C. Timmis, B.Sc., A.M.I.E.E., read a paper entitled "Carrier Current Telephony." The paper dealt exhaustively with the present state of the art, and the discussion and subsequent demonstration of apparatus designed by Capt. Timmis brought an interesting and instructive meeting to a close.

Informal Meetings.

On the 28th January, Mr. W. C. Burbridge, A.M.I.E.E., read a thought provoking paper entitled "Some Development Heresies." The subsequent discussion was prolonged and animated and the variety of opinions expressed amply justified the name of the subject. Mr. Burbridge fearlessly replied, and the meeting closed with a hearty vote of thanks to the author.

At the meeting on February 25th, Mr. A. Miller, A.M.I.E.E., read a paper entitled "London Building Acts." The attendance was disappointing in view of the care that had obviously been taken in preparing the paper. In the subsequent discussion many questions were asked and ably replied to by Mr. Miller.

NORTH WESTERN CENTRE.

A visit of inspection was paid to the Works of the Automatic Telephone Manufacturing Co., Ltd., Liverpool, on the 20th January, 1930. The firm very kindly afforded facilities for an inspection of the Tool Room, Machine Shops, Switch Assembly, Woodworking, Rack Assembly, Switchboard Wiring and Coil Winding Departments, also the Circuit Laboratory, etc. The visit proved most interesting and instructive and the thanks of the Centre are specially due to the Works Manager (J. Nixon, Esq.) for the general arrangements and to Messrs. Bell, Flenley, Maitland and Owen for conducting the members round the Works and for their lucid explanations of the various items and processes.

A meeting of the Centre was held at Preston on the 24th February, 1930, when a joint paper entitled "Blackpool Telephone Repeater

Station " was read by Mr. A. S. Carr, B.A. (Cantab.), A.M.I.E.E., and Mr. E. Hopper, A.M.I.E.E.

The Chairman of the Centre, Mr. J. M. Shackleton, M.I.E.E., presided.

The paper opened with a general survey of the subject of telephone transmission and the conditions which have to be satisfied in order to secure efficient results and comply with modern requirements. An outline of the equipment at Blackpool was then sketched with special reference to those features which are unique or of unusual interest, and the laying of the new Anglo-Irish cable was also touched upon.

The lecture was illustrated by lantern slides and specially prepared diagrams and was followed by a discussion. D. B.

NORTH EASTERN CENTRE.

Our Session was opened by the Chairman, Mr. J. W. Atkinson, M.I.E.E., who reviewed the activities of the Institution during the last 24 years and consequent upon his close association with the General Council and the I.P.O.E.E. Journal was in a position to furnish the members present with accurate information regarding the growth of the Institution. After dealing with the Institution, he spoke of the advance made in the Telephone Service during the last 50 years; the wonderful progress of Radio Communications, and the present position of Telegraphs, finishing his address with a look into the future, which even with the present " depression from Iceland " was hopeful.

Mr. Ritter's lecture on " Picture Telegraphy " furnished the majority of the members with information quite new to them, and the manner in which Mr. Ritter handled his subject was indicative of the keen interest he takes in it, which enabled him to speak as an authority.

Mr. R. T. Robinson's lecture on " Motor Transport "—fully illustrated by lantern slides —brought the members into close contact with an every day subject, and the discussion which followed showed that as yet the transport question is far from being solved. It is clear that within the next few years considerable advance in the use of Mechanical Appliances and Motor Transport by the Engineering Department will be made.

In December a large number of the members paid a visit to Messrs. Greenwood and Batleys Works at Armley, Leeds. This firm manufactures turbines, heavy testing machinery, torpedoes, cartridges, electrical machinery, electric lorries, etc., and the thorough manner in which the gentlemen who took charge of the parties explained the different spheres of the firm's activities caused the visit to be highly educative.

The second half of the Session was opened by Mr. A. Morris, of the Engineer-in-Chief's Office, on " Telephone Cable Interference."

The paper was circulated before the meeting, and Mr. Morris dealt with the more important points. The discussion proved of the utmost value to the members present, who raised questions of practical difficulties experienced, and Mr. Morris went to some trouble in explaining the causes of the difficulties, and the remedies to be applied.

The February meeting was taken in hand by one of our youngest members—Mr. H. E. Francis—" Rural Automatic Exchanges," who dealt with the subject in such a way as called forth the highest praise of all present. Rural Automatic Exchanges are practically new, and the details furnished as regards locality, site, building, lay-out, apparatus and maintenance, were very acceptable. A lengthy discussion followed which added materially to the value of the paper, as Mr. Francis cleared away many misunderstandings and difficulties, and the opinion was expressed that it is by the giving of such papers the value of the Institution's work is enhanced.

SOUTH LANCASHIRE CENTRE.

The third meeting of the Session was held on Monday, December 16th, 1929, when Major H. Yorke Starkey, of the Engineer-in-Chief's Office, read a paper on " The Maintenance Efficiency of Exchange and Subscribers' Apparatus." The paper gave suggestions for dealing with the comparison of maintenance costs on an equated unit basis, and also certain standards to be used as a basis for workmen's loads. Comparison was made between the effective work carried out in this country and in similar areas in America, and the author endeavoured to show that this

country could be reasonably expected to effect savings comparable with those which have already been effected in America. The paper, which included the results of experimental trials of the scheme in Liverpool and in Manchester, aroused a very fruitful discussion.

At the fourth meeting of the Session, held on January 13th, 1930, a paper entitled " Further Notes on Motor Transport in the Post Office Engineering Department and Mechanical Aids to Construction Work " was presented by Mr. R. T. Robinson, of the Engineer-in-Chief's Office.

On account of its length the paper was not read in full, but the author dealt with the salient points as each of the numerous lantern slides was displayed on the screen. In the discussion which followed many interesting points were raised, to which the author ably replied.

The fifth meeting of the Session was held at 7 p.m., on Tuesday, February 11th, 1930, when the members of the North Western Centre of the Institution of Electrical Engineers were present by invitation.

For this joint meeting the Institution was fortunate in arranging a lecture on " Talking Films " by Mr. S. S. A. Watkins, Recording Manager of the Western Electric Co. There were over 650 people present, including representatives of firms interesed in cinema production.

Mr. Watkins opened his remarks by saying that in the short time at his disposal it was impossible to give more than a superficial description of the subject. From his account, however, of the methods of recording, synchronisation and reproducing the sound pictures, members of the audience were able to obtain an excellent idea of the scientific principles applied to the problem and the manner in which the various difficulties had been overcome in achieving commercial success. The lecture was illustrated by a large number of excellent lantern slides.

Following the lecture Mr. Watkins ably dealt with a large number of interesting questions raised by members of his audience, and this gave added enjoyment to a very successful meeting.

Mr. Alfred James Eames.

Mr. A. J. Eames, Assistant Superintending Engineer in the South Lancashire District, retired on February 15th after nearly 45 years' service. After four years in the Central Telegraph Office, he transferred to the Clerical Staff of the Engineering Department. Eight years later he was appointed Sectional Engineer at Uxbridge and subsequently he moved to Shrewsbury and Liverpool. In 1923 he was appointed to the position of Assistant Superintending Engineer.

During his earlier engineering service, Mr. Eames was responsible for the re-building of some of the heaviest open trunk lines in the Home Counties. Whilst in Liverpool he served in both the Internal and External Sections and after the War carried through schemes of local development of considerable magnitude. During the war he rendered valuable service in connection with Coast Communications.

Farewell gatherings were held in Manchester and Liverpool. Mr. W. J. Medlyn, Superintending Engineer, Mr. T. E. Herbert, Assistant Superintending Engineer, and many other speakers, gave expression to the cordial relations which have always existed between Mr. Eames and all sections of the staff, and full tribute was paid to his high personal qualities.

A handsome piece of furniture was presented to Mr. Eames as a token of the regard and esteem in which he is held in the District.

NORTH WALES CENTRE.

The third meeting of the Session was held on 11th December, when Major G. A. Blackwell read a very interesting paper on " Fault Procedure," in which the procedure now in force was fully described and the uses of the various forms and records explained and commented upon. Members had previously been supplied with copies of the printed forms referred to by the lecturer and a discussion of considerable length ensued, during which some criticisms of the procedure were made, and pleas for simplification were entered. It is interesting to note that summaries of the opinions expressed by the speakers have been collected and an opportunity given to the Headquarters section most interested of perusing them, an opportunity, it should be mentioned, which has been welcomed and appreciated.

The fourth meeting was held on 8th January, 1930, when Captain N. F. Cave-Browne-Cave,

B.Sc., M.I.E.E., read a non-mathematical paper entitled " Sound " in which some of the most recent literature on this subject was explored and commented upon, with special reference to its bearing on telephony. The mechanism of hearing was described and illustrated, and the important effects of phantom sounds and other subjective phenomena were explained. Captain Cave had gone to considerable trouble in preparing slides, photographs and other exhibits, and his paper was listened to with rapt attention. At the conclusion of the discussion a very hearty vote of thanks was passed, with complimentary references to his ability to make a scientific subject highly interesting and entertaining.

The fifth meeting was held on 12th February, on which occasion we had the pleasure of a visit from a Headquarters Officer, who read a paper on his special subject. This was Mr. A. Morris, A.R.C.Sc., M.I.E.E., of the Research Section, Engineer-in-Chief's Office, whose paper was on " Telephone Cable Circuit Interference." The written paper was a somewhat technical one, but Mr. Morris, instead of keeping close to his copy, launched out into a more digestible extempore explanation of many of the forms of interference and of the means of overcoming them. The ensuing discussion was of such length that it had to be closured on the approach of train time.

I.E.E.: WESTERN CENTRE.

The annual dinner was held at the Royal Hotel, Cardiff, on 13th January, when there was a large attendance of members and guests, the latter including many ladies. Mr. Sidney B. Haslam, Chairman of the Centre, presided and the company included Col. Sir Thomas Purves (President of the Institution), Sir Felix J. C. Pole, Alderman William Walker, Principal George Knox, Mr. C. G. Morley New, Mr. J. W. Beauchamp, etc., etc. The South Wales District staff of the Post Office was represented by Mr. J. S. Terras, Superintending Engineer.

In replying to the toast of the Institution, proposed by Alderman Walker, Sir Thomas Purves said he desired to acknowledge the great work which was being done by the Western Centre. The success of the Centre showed very pointedly that London was not the sole fountain of wisdom in the Institution.

The toast of " Kindred Societies and Guests," proposed by Mr. Morley New, was responded to by Principal Knox and Sir Felix Pole. Other speakers were Mr. Beauchamp, Mrs. D. Watts-Morgan, Mrs. Morley New, Brig.-Gen. C. G. Bruce and Mr. Walter Bache.

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C.T.O.,
Colombo,
Ceylon.

A. J. Kellaway, Esq.,
Department of Posts and Telegraphs,
P.O. Box 366,
Pietermaritzburg,
South Africa

CURRENT LITERATURE.

The Journal of the Institution of Electrical Engineers, Vol. 68, No. 396, Dec., 1929.

Inaugural address. Col. Sir T. F. Purves, President. A summary of the address has already been published. See January issue of this Journal.

Chairman's address from the following subsections are given: Wireless, Meter and Instrument, Western, South Midland, Irish, North-Eastern, North-Western, Mersy and Wales, North Midland, Scottish, East Midland, Dundee, Sheffield and Hampshire.

Vol. 68, No. 397, January, 1930.

The Analysis and Measurement of Noise emitted by Machinery. A. G. Churcher and A. J. King.

Progress Reviews: Electro Physics, Electrical Plant and Machinery including Marine, Domestic Applications of Electrcity, Supply Tariffs and Methods of Change, The Electrical Equipment of Automobiles, and Electric Traction.

Some Measurements in Cornwall of the Signal Strentgth from 5 XX. J. H. Reyner, B.Sc.

Vol. 68, No. 398, February, 1930.

Low Temperature Carbonization of Fuel: American, German and English practice. S. McEwen, Prof. P. Rosin, E. H. Smythe and E. G. Weeks.

Naval Wireless Telegraph Communications. G. Shearing, B.Sc., and Capt. J. W. S. Dorling.

The Valve Maintained Quartz Oscillator. J. E. P. Vigoureux, M.Sc.

High Frequency Resistance Measurement by the use of a Variable Mutual Inductance. W. Jackson, M.Sc.

Journal of the American Institution of Electrical Engineers.

Vol. XLVII., No. 12, December, 1929.

Series Synchronous Condensers for Generation of Voltage consumed by Line Inductance. Theodore H. Morgan.

Annual Reports of Committees on Electro Chemistry and Electrometallurgy, on Transportation, Marine Work and General Power.

Current Transformer Excitation under Transit Conditions. D. E. Marshall and P. O. Longguth.

Spray and Fog Tests on 220-Kv Insulation. R. J. C. Wood.

Audio Frequency Transformers. Voltage-Ratio Characteristics determined by the Low Voltage Cathode Ray Oscillograph. Paul Klev, Jr., and D. W. Shirley, Jr.

Vol. XLIX., No. 1, January, 1930.

The Chicago Long Distance Toll Board. E. O. Neubauer and G. A. Rutgers. The Chicago Toll Office, serving 1,200,000 stations, has recently been supplied with new equipment. The new plant and lines are described and compared with former methods.

Magnetic Circuit Units. A. E. Kennelly. A discussion of the historical developments of magnetic circuit units and proposals *re* standardisation.

Theory of a New Valve Type Lightning Arrester. J. Slepian, R. Tanberg and C. E. Kaause.

Ionization Currents and the Breakdown of Insulation. J. J. Torok and F. D. Fielder.

Air Transport Communication. R. L. Jones and F. M. Ryan. Successful operation of transport service requires rapid and dependable communication between plane and ground. Two-way telephony provides this.

Vol. XLIX., No. 2, February, 1930.

Transoceanic Telephone Service: General Aspects. T. G. Miller. Extent and growth of service since 1927 are outlined. At present 85% of world's telephones are included in area served and 50 calls are made per business day. Plans for future are outlined.

Three Regions of Dielectric Breakdown. P. H. Moon and A. S. Norcross.

Experience with Carrier-Current Communication on a H.T. Inter-connected Transmission System. Philip Sporn and Ray H. Wolford.

Descriptive of system on 132 Kv network, 2500 miles long, is given.

Journal of the Franklin Institute. Vol. 209, No. 1, January, 1930.

Unbraced Cables. Jacob Feld, C.E., Ph.D. Usual methods of design for long spans are inaccurate, because they omit elastic stretch. Equations are derived to cover all possible cases, loaded and unloaded, allowing for variations of temperature and movement of supports. Bibliography included.

BOOK REVIEWS.

" High Voltage Cables." By L. Emanuelli, M.I.E.E., M.Amer.E.E. 107 pp. Published by Messrs. Chapman & Hall. Price 8/6 net.

This book, based on a course of lectures prepared for the Engineering Faculty of the University of London by Mr. Emanuelli, deals, as would be expected in an informative manner with modern high voltage cables, and like Mr. Dunsheath's book,* recently reviewed, can be thoroughly recommended to engineers and students, the two books being to a certain extent complementary.

The first part is introductory and gives a short outline of the manufacture of a paper insulated cable and then deals with the materials used, first the paper and then the impregnating compound, and the effects of varying the proportions of oil and resin. Tests on the materials and methods of preparation are described.

The electrostatic field set up in the cable is dealt with at length, this being of course of great importance as directly the field ceases to be uniform the voltage gradient through the insulation is affected and the risk of breakdown increased. After dealing with dielectric losses the author passes on to the actual impregnation of the cable and the means employed to obtain uniform saturation without the formation of gas bubbles, the presence of which entirely alters the designed stresses and leads to breakdown of the cable.

The final chapter deals with the mechanical and electrical properties of the finished cable and finally with the oil filled cable now being used successfully for very high voltages. The book is well illustrated throughout. J. McG.

* *" High Voltage Cables," by P. Dunsheath, O.B.E., M.A., B.Sc., M.I.E.E.*

" Le Système de Télégraphie Baudot et ses Applications." Par P. Wercy. Pp. viii. + 640: 4th edition. Paper covers 56 francs: Bound 66 francs.

This standard book on the Baudot multiplex system was written primarily as a course of instruction for French dirigeurs. The first section contains a complete description of the apparatus, methods of synchronism, and wiring of the system. Detailed descriptions of the adjustments, electrical and mechanical, are given in the second section.

The third section deals with the flexibility of the system to traffic requirements and describes fully the method of extending channels by the system échelonée and by retransmitters. Chapters are also included on the application of duplex to the system and the Picard method of correction from signals.

It is interesting to note that the extensive use of three and four station working in France is apparently confined to simplex circuits. No description of a duplex three station circuit is given.

Modern developments are dealt with in the last section which has been brought up to date by the inclusion of descriptions of the Doignon-Wendonça-d'Oliveira Governor, automatic working on the Murray system, the Verdan method of eliminating the effect of atmospherics on Baudot reception when used on radio communications, and methods of Voice frequency working.

The book is well illustrated with over 260 figures and the price compares very favourably with similar types of British technical works.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	Grade.	Promoted to	Date.
Robinson, C.	Assistant Staff Engineer, Research Section, E.-in-C.O.	Staff Engineer, Test Section, E.-in-C.O.	31-1-30
Horner, F. H.	Executive Engineer, Shrewsbury Section, N. Wales District.	Assistant Staff Engineer, E.-in-C.O.	19-12-29
Gill, A. J.	Executive Engineer, Radio Section, E.-in-C.O.	Asst. Staff Engineer, Radio Section, E.-in-C.O.	19-12-29
Morris, A.	Assistant Engineer, Research Section, E.-in-C.O.	Executive Engineer, Radio Section, E.-in-C.O.	19-12-29
Bell, R. W. S.	Assistant Engineer, Technical Section, S. Lancs. District.	Executive Engineer, Shrewsbury Section, N. Wales District.	5-1-30
Prentice, D. B.	Skilled Workmen Cl. I., Scot. West District.	Inspector, Scot. West District.	23-1-29
Milton, G. F. A.	Skilled Workmen, Cl. I., E.-in-C.O.	Inspectors, E.-in-C.O.	23-10-28
Cook, A. C.			23-10-28
Evans, A. F. E.			23-10-28
King, E. F. H.			11-11-28
Blackhall, W. A. C.			11-11-28
Denyer, W. C.			4-11-28
Stewart, A. D.			18-11-28
Osborne, W. V.			30-9-28
Corkett, H.			4-11-28
Lidstone, F. J. W.			4-11-28
Dennison, R. F. A.			2-12-28
Siems, C. V.			4-11-28
Tilly, C. N.			23-1-29
Jeynes, E. H.	Skilled Workmen, Cl. II., E.-in-C.O.	Inspector, E.-in-C.O.	20-7-29
Lush, A.	Skilled Workmen, Cl. I., S. East District.	Inspector, S.E. District.	2-3-29
Sharpe, G. E.	Skilled Workmen, Cl. I., N. Mid. District.	Inspector, N. Mid. District.	To be fixed later.
Ostins, P. C.	Skilled Workmen, Cl. I., N. Wales District.	Inspectors, N. Wales District.	15-2-30
Grigg, C. E.			1-1-30
Ovenall, E. W.			7-2-29
Davis, A. T.			17-4-29
Whittingham, L.			21-11-29
Beattie, M.	Skilled Workmen, Cl. I., Scot. West District.	Inspector, Scot. West District.	To be fixed later.
Finney, C. W. Mc. S.	Skilled Workmen, Cl. I., S. Lancs. District.	Inspector, S. Lancs. District.	"

APPOINTMENTS.

Name.	From	To	Date.
Legg, G. E.	Probationary Inspectors.	Inspectors.	1-11-29
Barker, H.			1-1-30
Hall, L. L.			"
Stanton, E. P.			"
Purvis, C.			"
Clarke, C. W.			"
Ward, W. C.			"
Calveley, C. E.			"
Sheppard, J. A.			"
Jackson, G.			"
Morley, J. E.			"
Hawkins, C. F. W.			"
Farren, P. E.			"
Jago, W. G.			"

PROMOTIONS—*continued.*

Name.	From	To	Date.
Brett, S. I.	Limited Competition.	Probationary Assistant Engineers.	28-1-30
Richards, C. E.			9-2-30
Affleck, D. B.			9-2-30
Penney, A. E.			26-1-30
Stanesby, H.			9-2-30
Flowers, T. H.			9-2-30
Scantlebury, L. F.	Open Competition.		10-2-30
Pearson, A. W. C.			10-2-30
Harrison, G. B. W.			10-2-30
Hibbs, A.			19-1-30
Harmston, A. T.			20-2-30
Warren, F.	Limited Competition.	Probationary Inspectors.	23-2-30
Charles, F. N.			,,
Duff, J. B.			,,
Smith, J.			,,
Hodges, P. G. L.			,,
Hunt, A. M.			,,
Gerrard, J.			,,
Gray, R. E.			,,
How, S. F.			,,
Smith, C. N.			,,
Atherton, W. S.			2-3-30
Pratt, F. A. N.			23-2-30
Davis, S.			,,
Druett, L. W.			,,
Donovan, J. G.			,,
Gill, E. S. A.			,,
Cottenden, S. E.			,,
Wooding, W. T.			9-3-30
Green, R. G.	Open Competition.	Probationary Inspectors.	24-2-30
Amos, A. J.			3-3-30
Seaman, E. C. H.			23-2-30
Franklin, G.			

RETIREMENTS.

Name.	Rank.	Districts.	Date.
Eames, A. J....	Assistant Suptg. Engineer.	S. Lancs.	15-2-30
Burton, G. M.	Executive Engineer.	N. East.	22-2-30
Ryall, J. B.	,, ,,	S. Wales.	20-3-30
Stone, H. C.	,, ,,	London.	31-3-30
Horton, F. D.	,, ,,	S. Mid.	31-3-30
Billingham, G. W.	,, ,,	N. Wales.	15-1-30
Wyatt, J.	Assistant Engineer.	N. Mid.	31-3-30
Hammond, E. J.	,, ,,	E.	23-1-30
Cooper, J. O.	,, ,,	S. Lancs.	31-12-29
Kay, C. P.	,, ,,	N.	31-12-29
McAllan, J.	Chief Inspector.	Scot. East.	28-2-30
Burnett, A. T.	,, ,,	S. Wales.	1-2-30
Chambers, C.	,, ,,	S. Lancs.	31-12-29
Laney, J. W.	Inspector.	London.	6-2-30
Hollis, T.	,,	N. Wales.	2-2-30
O'Leary, A. J.	,,	S. West.	7-1-30
Price, A. W.	,,	S. Wales.	1-12-29
Bayliss, A. E. H. V.	,,	N. Wales.	31-12-29
Forrester, J.	,,	Scot. West.	5-1-30
Dykes, E. H.	,,	London.	31-12-29
Quilter, H. J.	Draughtsman Class I.	E.-in-C.O.	31-1-30

RESIGNATIONS.

Name.	Rank.	District.	Date.
Pollock, S. A.	Staff Engineer.	Research Section, E.-in-C.O.	31-12-29

DEATHS.

Name.	Rank.	District.	Date.
Sly, R. C.	Inspector.	London.	27-12-29

CLERICAL ESTABLISHMENT.

RETIREMENTS.

Name.	Grade.	District.	Date.
Loney, H. J.	Executive Officer.	Engineer-in-Chief's Office.	31-12-29
Cowley, P. J.	,, ,,	,, ,,	25-1-30
Morris, G. L.	Higher Clerical Officer.	N. Midland.	10-3-30
Atkinson, E. W.	,, ,,	London District.	28-3-30
Griffiths, E. F.	,, ,,	,, ,,	31-3-30
Mountain, W. S.	Principal Clerk.	Engineer-in-Chief's Office.	31-3-30

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THE
Post Office Electrical Engineers' Journal

PICTURE TELEGRAPHY.
SIEMENS—KAROLUS—TELEFUNKEN SYSTEM.

G. E. CARR.

THIS article deals chiefly with the particular photographic equipment and methods employed at the P.O. installation, G.P.O. (West), London. An article describing the general systems of Phototelegraphy (Belin, Bell and Siemens-Karolus) was published in this Journal in October, 1928, and a description of the London Official Station was given in last April issue.

In phototelegraphy the ideal transmission condition is to reproduce all the tones and half tones which may be present in the original to be transmitted.

DESCRIPTION OF DARK ROOM AND APPARATUS.

The present apparatus is designed for dish development by time and inspection methods.

Entrance to the Dark Room is by a specially curtained doorway, giving free entrance and exit at any time without permitting white light to enter. The outer and inner curtains are arranged on runners so that they can easily be drawn aside and close the opening again when released. The interior of this entrance chamber is painted dead black, but the dark room itself is in the usual colours used for office decoration, cream and blue-grey.

The floor is asphalte, covered with strips of lino. This latter has proved to be unsatisfactory when wet and will be replaced with fluted india-rubber matting.

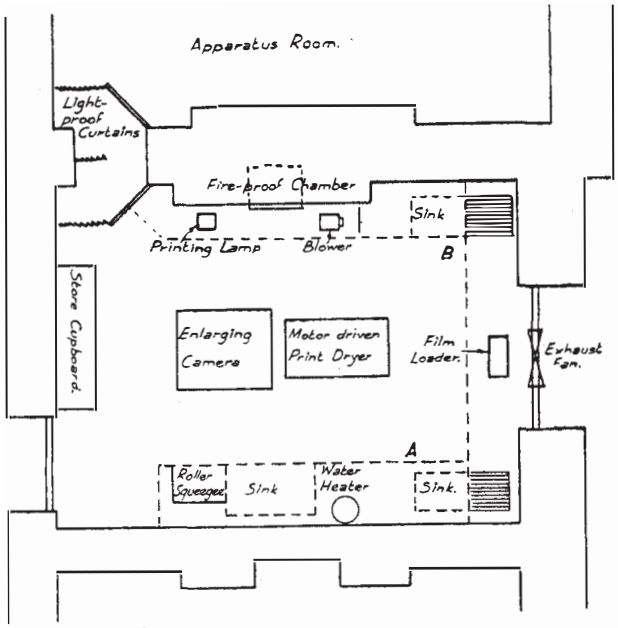


FIG. 1.—LAY-OUT OF DARK ROOM.

Making a tour round the dark room, the bench on the left has drawers in which are kept the various grades of printing paper. Suspended above this bench is the lamp used for making exposures by contact in a printing frame. This lamp is fitted into one of the standard type of

dark room lamps and the intensity of the light can be reduced readily by using one or more sheets (10 × 8) of opal or ground glass. When exposing a gaslight paper the direct light is used. By this means the exposure for various negatives and papers may be kept within reasonable limits, *i.e.*, not too fast for a soft bromide or too slow for a gaslight paper.

Sunk into the wall just above the bench is a sheet steel chamber fitted with a drop shutter. This contains the stock of unexposed celluloid films.

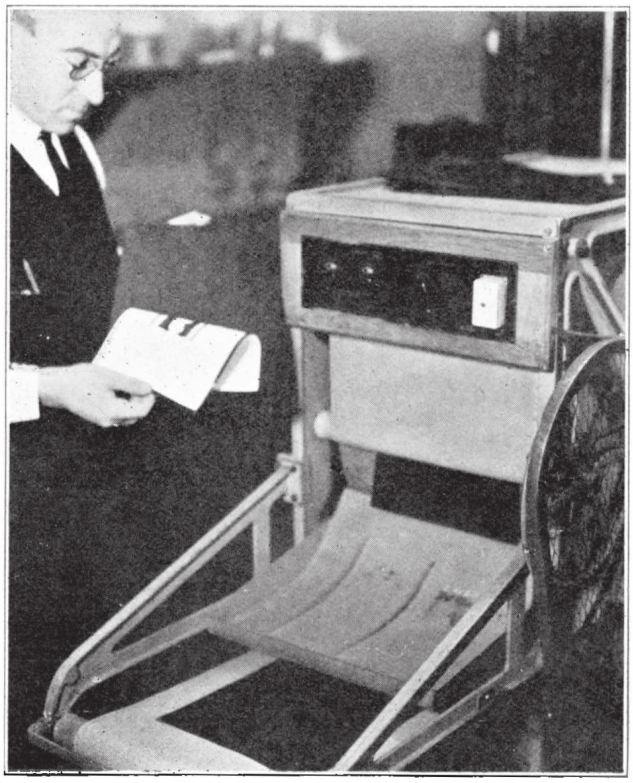


FIG. 2.—PRINT DRYER.

To the right is the apparatus used for drying the developed film. It consists of an electric air blower, giving hot or cold air, such as is used for drying purposes; in principle it is the same as the machines used for "Hair-drying," but is much more robust. The heater and fan are designed to deliver 600 cu. ft. of air per minute at a temperature of approx. 50°F. above room temperature.

The film (which is unbacked) to be dried is pinned upon a board placed in front of the fan. The exposed prints are developed at position B (See Fig. 1), where the developing dish, hypo bath and sink are together. Over the hypo bath is suspended a white light for close inspection of a print.

The automatic film loader is shown below the ventilating fan. In this part of the room the stock of developers is prepared from raw materials.

On the bench at the right, development of the film is carried out. On the right hand side of the sink is the developing bath and on the left the special hypo bath and hardening bath.

The warm water used for the rapid washing of films and prints is drawn from a thermostatically controlled water heater affixed to the wall to the left of the large lead lined sink, in which the washing operations are carried out.

At the end of the bench is a roller pattern squeegee machine used in the glazing process for prints.

In the centre of the room is the enlarger and, alongside, the print dryer. The enlarger is of the vertical condenserless type capable of taking negatives 12″ × 10″ in the carrier and is fitted with a 12″ focus Cooke Aviar lens F4.5.

The illuminant is a mercury vapour arc in the M form tube contained in a lamp house, the diffusion sheets of opal or ground glass being fixed between this and the negative.

The negative carrier in the horizontal position is convenient for taking wet films. The M.V. lamp is operated by an automatic starter; this saves much time and enables accurate exposures to be made.

Graduated scales fitted to the vertical supports and the camera of the enlarger facilitate the copying, reduction or enlarging of a negative.

The print dryer, Fig. 2, is of the rotary type, consisting of an endless canvas band which passes over a rotating drum, containing two electric heating elements. The speed of rotation and temperature of the drum can be regulated from a small switchboard on the machine.

When in use, the general illumination comes from two ceiling reflector lamps, 12 × 10, one dark red and the other deep orange; the latter is used generally, but not when film loading or negative developing is being carried out. At convenient points are situated smaller safelights, 7″ × 5″, and the switches controlling these are readily reached from the developing positions.

Two low temperature radiators of 3 kW capacity fitted with three heat control switches are situated under the benches. By means of these the room can be readily maintained at a temperature of 75°—78°F., which is the normal working temperature. A recording thermometer is situated in a position to register the temperature variations.

Ventilation is provided by an exhaust fan fitted within the framework of the window, which is boarded to exclude all white light. The fan has a capacity of 30,000 cu. ft. per hour, and is fitted with a speed regulator. Whilst this is more than ample for general ventilation, it is necessary to remove as quickly as possible the formaldehyde given off by the hardening baths and during the glazing process.

All sinks are fitted with spray nozzles on swing arms and separate $\frac{1}{2}$" bib cocks. In the large sink is a $\frac{3}{4}$" tap fitted with an " antisplash " used for the rapid washing of films.

A timing clock having a large dial (see Fig. 3)

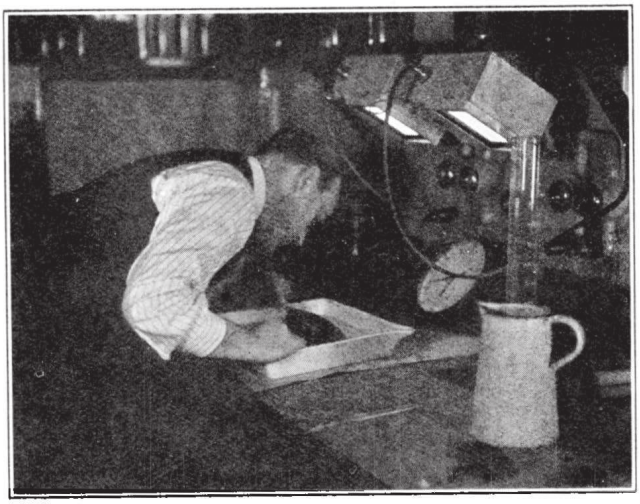


Fig. 3.—Developing Films.

and a swinging pendulum, which rings a bell each second, is used for the timing of exposures and operations.

Cupboards with sliding doors are fitted beneath the benches and shelving is provided for bottles and solutions, etc.

Description of Operations.

The film used by the Department is supplied by a well known British firm manufacturing photographic materials and is similar to that used by many of the newspapers who employ phototelegraphy.

The particular film used is single coated (*i.e.*, minus gelatine on the back). The celluloid base is 18.4 × 27.2 cms. and 5/1000 inch thick and the emulsion is rated at 500 H and D.

To load a receiving cylinder the dark slide containing a cylinder is placed in a carrier which slides on the rails of the special loading machine, Fig. 4. By moving the carrier with a sliding motion the cylinder engages on a tapered cone

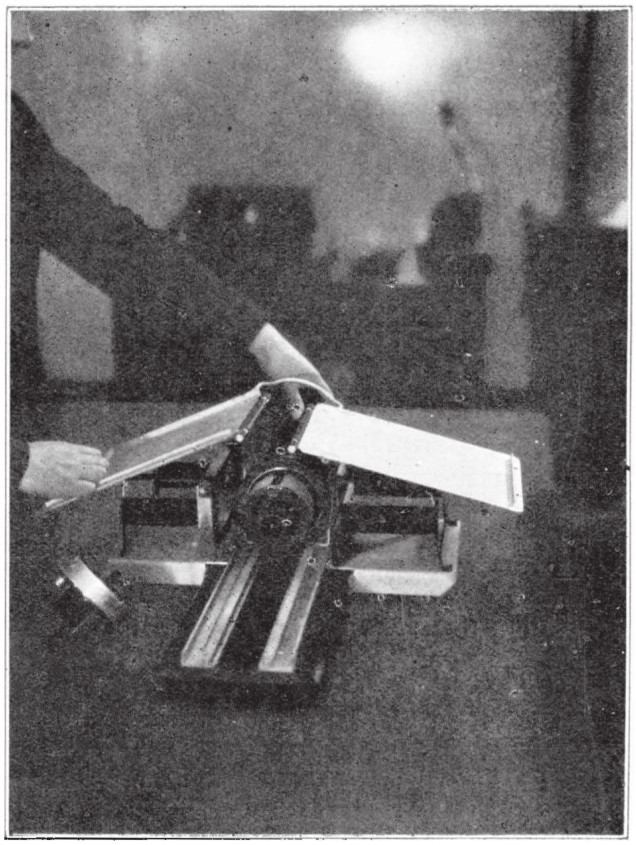


Fig. 4.—Preparing to load Receiver Cylinder with Unexposed Film.

mandril, which is the same size and shape as that on the receiver spindle, and the outer dark slide passes along to the end. One end of the film is clipped to the cylinder and, by turning a milled head fitted with a ratchet, it is wrapped round the cylinder and the end is then clipped on to the latter. By this means, handling of the film is avoided.

Assuming that exposure has taken place, the film is unclipped, and the top right hand corner

turned up and creased. This serves two purposes, identification of direction of running, etc., and provides a means of lifting the film from the solutions.

Development is carried out in a dish using a metol - hydroquinone developer. Experiments have shown the following composition to be suitable for these films :—

Metol	1.75	grams.
Hydroquinone ...	4.0	,,
Sodium Sulphite ... (Anhydrous salt).	75	,,
Sodium Carbonate ... (Anhydrous salt).	35	,,
Potassium Bromide ...	1.5	,,
Water to	1000	,,

This formula compares favourably with many well balanced M.Q. developers, with the exception that the alkaline content—Sodium carbonate —is a little higher, which quickens the developer.

At a temperature of 75° the Watkin factor for this developer is 4.5 to 5 and complete development normally takes place in 1.75 minutes. When developing black and white transmissions the Watkin factor is increased to 6½ to give greater density.

After a brief rinse in running water the film is transferred to a rapid acid fixing bath, composed of :—

Sodium Thiosulphate ...	200 gm.
Potassium Meta-bisulphite .	25 ,,
Ammonia Chloride ...	35 ,,
Water to	1000 cc.

With continued rocking, the emulsion is cleared in about 1½ minutes. This time clears the film, but does not necessarily "fix" the emulsion, as there are left double salts of silver and ammonia, but these in no way effect the density of the deposit.

The film is then washed for two minutes under the full jet of water from the tap in the large sink. During this period the major portion of the thiosulphates is washed from the film.

Hardening the gelatine film is done by immersion for 1½ minutes in the following solution :—

Formaldehyde 40% solution..	1 part.
Water to	9 parts.

When not in use this bath is kept in a covered case to prevent inconvenience caused by the irritating vapour of formaline.

A further washing of two minutes is given, finishing with warm water, when the surplus moisture is removed from the gelatine by means of a pad of chamois leather.

If a print only is required, the film negative is squeegeed to a glass support, and the positive is made by means of the enlarger. The major portion of the received work is of a topical pictorial character for press agencies and newspapers, who require the delivery of the actual film. In these cases the wet film is pinned upon the special drying board and the hot air blast started, Fig. 5. Drying is usually completed in 4½-5 minutes.

Fig. 5.—Fixing Film for Drying.

It is necessary to make two copies for record purposes from all films delivered and this is the next step.

The following procedure applies to both methods of printing, *i.e.*, through the enlarger or by contact in a printing frame.

The negative is viewed and, according to its density and contrast, a suitable printing paper is used for the positive.

The stock of printing papers, which all are "Glossy," consists of soft, normal and hard bromide emulsions and soft and vigorous chlorobromide (silver chloride) emulsions, supplied by well-known makers.

The type of negative obtained depends upon:

1. Voltage on receiving lamp.
2. Voltage on Kerr Cell.
3. Setting of Nicol prisms.
4. Black and white original transmitted without compensation.
5. Tone scale original transmitted with various compensations.
6. Photographic treatment of exposed emulsion.

1, 2, 3 and 6 are variables, which are controlled at the receiving end and are adjusted within certain limits to suit the type of film used.

Where the original is black and white in character (or devoid of any half tones) it is transmitted without compensation and advantage is taken of the characteristic curve of photographic emulsions. The resulting negative has only two tones, one very light and the other of full density. Any short-range printing paper is suitable for printing from such a negative.

If too little or too much compensation is given distortion of the tone scale results. Too little has the effect of producing a hard negative and loss of low shadow tones, whilst over compensation produces a flatness similar in effect to "over exposure" in ordinary photography.

This flatness may to some extent be corrected by using a suitable printing paper having a short exposure scale.

By alteration of the electrical circuit arrangement of the picture and compensation photo cells, "Positive" reception can be made when the receiver drum is loaded with a sheet of rapid bromide paper in place of a negative film and, by the usual development, a positive print is obtained direct.

Provision is made in the switching arrangement of the apparatus for the following conditions:—

Transmitted.	*Received.*
Positive Print.	Negative Film.
,, ,,	Positive Print.
Negative Film.	,, ,,
,, ,,	Negative Film.

Experiments show that three types of film emulsion and three kinds of bromide printing papers will cover all the required conditions on the photographic side.

The developer used for printing paper is that suggested by the makers of the particular paper.

The print, after development, is transferred, after washing for a brief period, to an acid fixing bath and vigorously agitated for a few seconds, to stop the action of the developer. Inspection is then made with a white light and, if necessary, reference is made to the negative to ascertain that a reasonably correct exposure has been made.

It has been shown by Warwick that, providing a print is vigorously agitated in a fresh fixing bath, fixation takes place very rapidly and is of the order of 30 seconds.

Following a washing in a turbine pattern washer, the print is transferred to a bath containing a glazing solution. This bath is composed of formaline, oxgall and water. The positive is then transferred to a ferrotype glazing sheet, 14 × 10, previously swabbed with the glazing solution and, after being squeegeed by hand, is placed between fluffless blotting sheets and passed twice through the roller squeegee to remove the surplus moisture and ensure even contact between the print and the glazing support. After passing through the print dryer, which takes about seven minutes, the print is stripped off the ferrotype sheet and is ready for enclosing in an envelope for delivery in the usual way.

The following table indicates the time taken to produce (1) a finished film and (2) a finished print:—

(1)	Development	2 minutes.
	Washing	5 seconds.
	Fixing	1½ minutes.
	Washing	2 ,,
	Hardening	1½ ,,
	Washing	2 ,,
	Drying	5 ,,
	Total	14 mins. 5 secs.

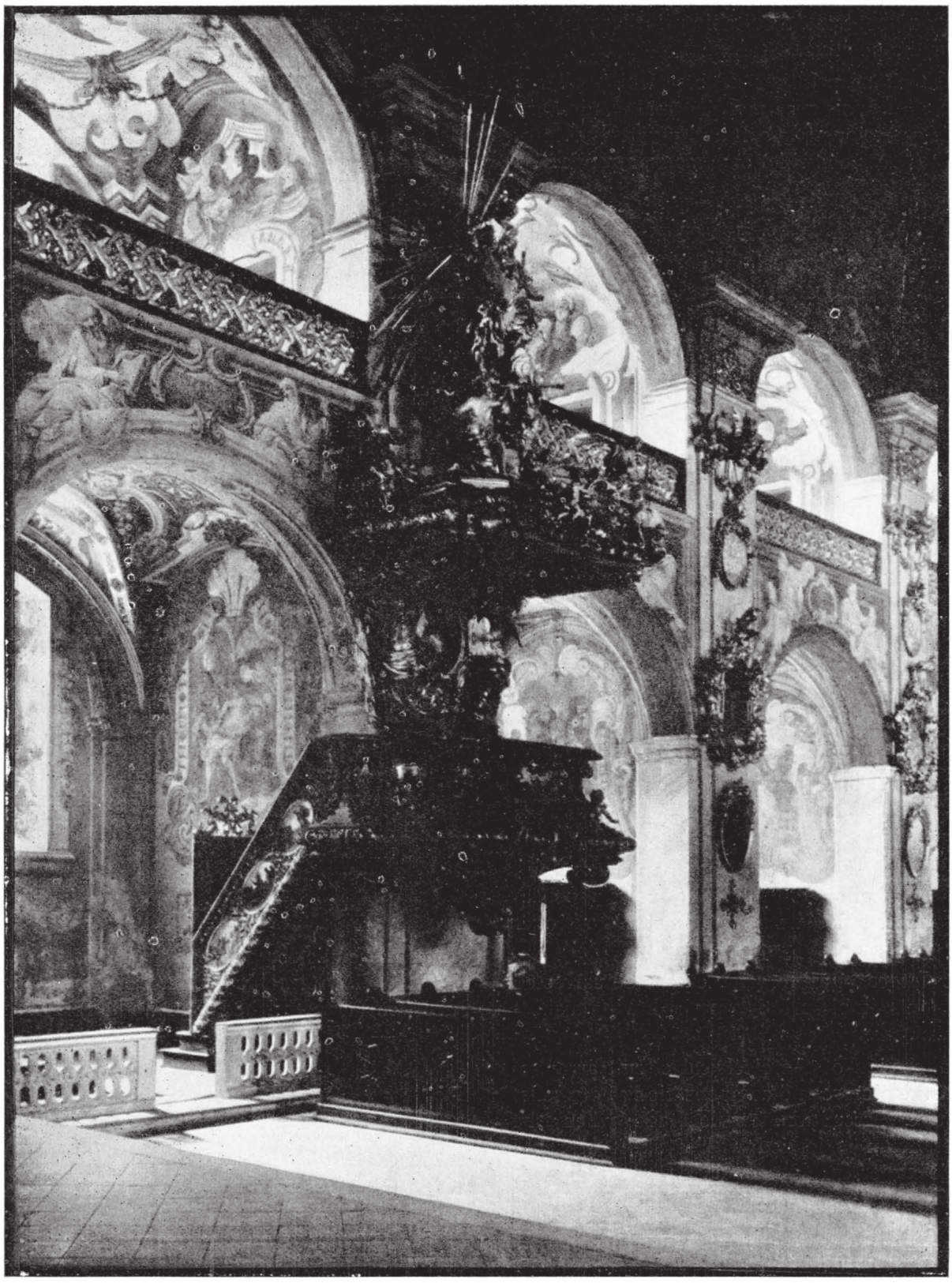
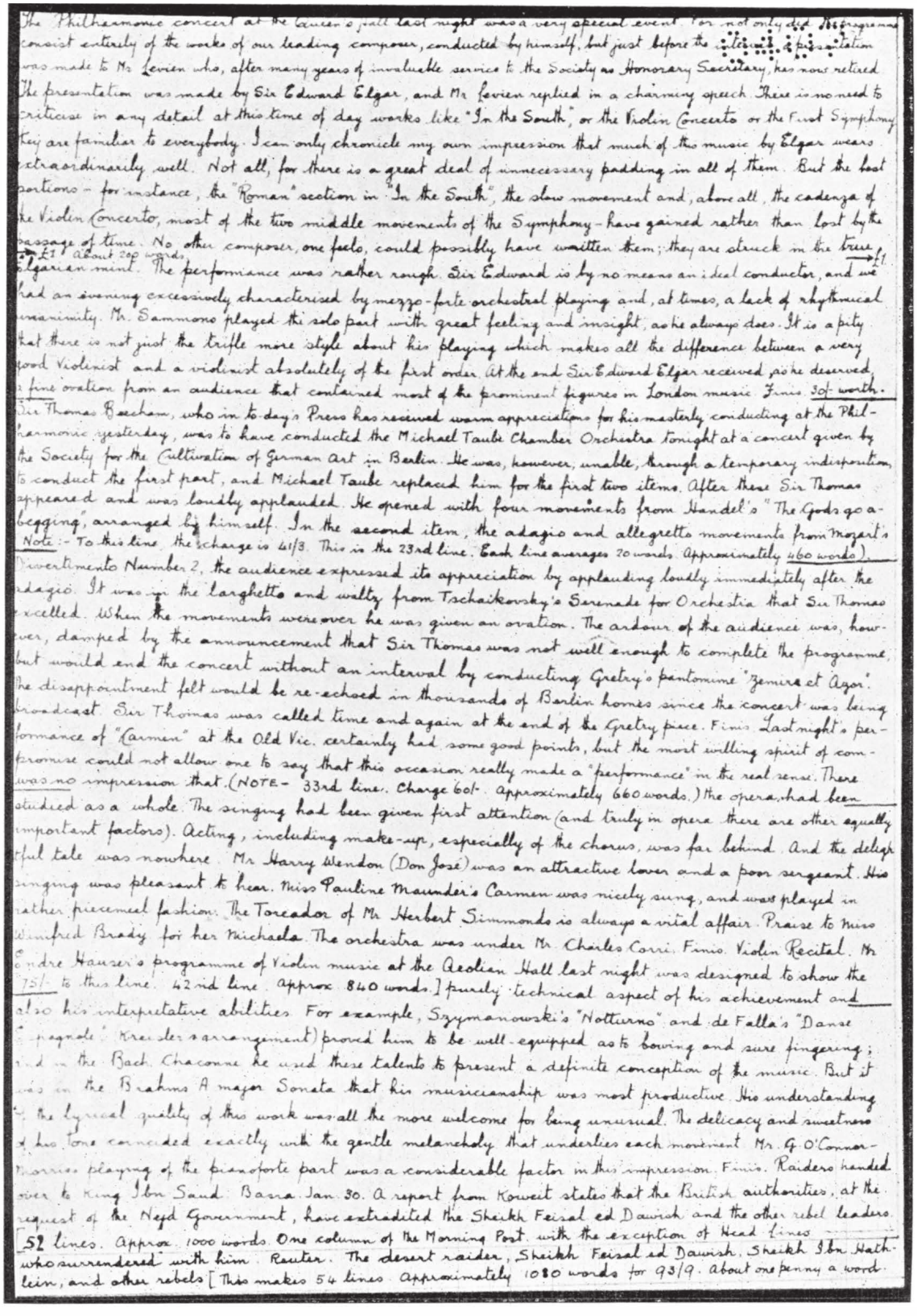


FIG. 6.—SPECIMEN OF RECEPTION, LONDON-MUNICH.


The Philharmonic concert at the Queen's Hall last night was a very special event. For not only did the programme consist entirely of the works of our leading composer, conducted by himself, but just before the interval a presentation was made to Mr. Levien who, after many years of invaluable service to the Society as Honorary Secretary, has now retired. The presentation was made by Sir Edward Elgar, and Mr. Levien replied in a charming speech. There is no need to criticise in any detail at this time of day works like "In the South," or the Violin Concerto or the First Symphony. They are familiar to everybody. I can only chronicle my own impression that much of the music by Elgar wears extraordinarily well. Not all, for there is a great deal of unnecessary padding in all of them. But the best portions - for instance, the "Roman" section in "In the South", the slow movement and, above all, the cadenza of the Violin Concerto, most of the two middle movements of the Symphony - have gained rather than lost by the passage of time. No other composer, one feels, could possibly have written them; they are struck in the true Elgarian mint. The performance was rather rough. Sir Edward is by no means an ideal conductor, and we had an evening excessively characterised by mezzo-forte orchestral playing and, at times, a lack of rhythmical unanimity. Mr. Sammons played the solo part with great feeling and insight, as he always does. It is a pity that there is not just the trifle more style about his playing which makes all the difference between a very good violinist and a violinist absolutely of the first order. At the end Sir Edward Elgar received, as he deserved, a fine ovation from an audience that contained most of the prominent figures in London music. Finis. 30/- worth.

Sir Thomas Beecham, who in to-day's Press has received warm appreciations for his masterly conducting at the Philharmonic yesterday, was to have conducted the Michael Taube Chamber Orchestra tonight at a concert given by the Society for the Cultivation of German Art in Berlin. He was, however, unable, through a temporary indisposition, to conduct the first part, and Michael Taube replaced him for the first two items. After these Sir Thomas appeared and was loudly applauded. He opened with four movements from Handel's "The Gods go a-begging," arranged by himself. In the second item, the adagio and allegretto movements from Mozart's Divertimento Number 2, the audience expressed its appreciation by applauding loudly immediately after the adagio. It was in the larghetto and waltz from Tschaikovsky's Serenade for Orchestra that Sir Thomas excelled. When the movements were over he was given an ovation. The ardour of the audience was, however, damped by the announcement that Sir Thomas was not well enough to complete the programme, but would end the concert without an interval by conducting Gretry's pantomime "Zemire et Azor". The disappointment felt would be re-echoed in thousands of Berlin homes since the concert was being broadcast. Sir Thomas was called time and again at the end of the Gretry piece. Finis. Last night's performance of "Carmen" at the Old Vic. certainly had some good points, but the most willing spirit of compromise could not allow one to say that this occasion really made a "performance" in the real sense. There was no impression that (NOTE - 33rd line. Charge 60/- Approximately 660 words.) the opera had been studied as a whole. The singing had been given first attention (and truly in opera there are other equally important factors). Acting, including make-up, especially of the chorus, was far behind. And the delightful tale was nowhere. Mr. Harry Wendon (Don José) was an attractive lover and a poor sergeant. His singing was pleasant to hear. Miss Pauline Maunder's Carmen was nicely sung, and was played in rather piecemeal fashion. The Toreador of Mr. Herbert Simmonds is always a vital affair. Praise to Miss Winifred Brady for her Michaela. The orchestra was under Mr. Charles Corri. Finis. Violin Recital. Mr. Andre Hauser's programme of violin music at the Aeolian Hall last night was designed to show the [75/- to this line. 42nd line. Approx. 840 words.] purely technical aspect of his achievement and also his interpretative abilities. For example, Szymanowski's "Notturno" and de Falla's "Danse Espagnole" (Kreisler's arrangement) proved him to be well-equipped as to bowing and sure fingering; and in the Bach Chaconne he used these talents to present a definite conception of the music. But it was in the Brahms A major Sonata that his musicianship was most productive. His understanding of the lyrical quality of this work was all the more welcome for being unusual. The delicacy and sweetness of his tone coincided exactly with the gentle melancholy that underlies each movement. Mr. G. O'Connor-Morris's playing of the pianoforte part was a considerable factor in this impression. Finis. Raiders handed over to King Ibn Saud. Basra. Jan. 30. A report from Koweit states that the British authorities, at the request of the Nejd Government, have extradited the Sheikh Faisal ed Dawish and the other rebel leaders [52 lines. Approx. 1000 words. One column of the Morning Post with the exception of Head Lines who surrendered with him. Reuter. The desert raider, Sheikh Faisal ed Dawish, Sheikh Ibn Hathlein, and other rebels [This makes 54 lines. Approximately 1080 words for 93/9. About one penny a word.

FIG. 7.—SPECIMEN OF RECEPTION. A COMPETITOR TO HAND AND MACHINE TELEGRAPHS.

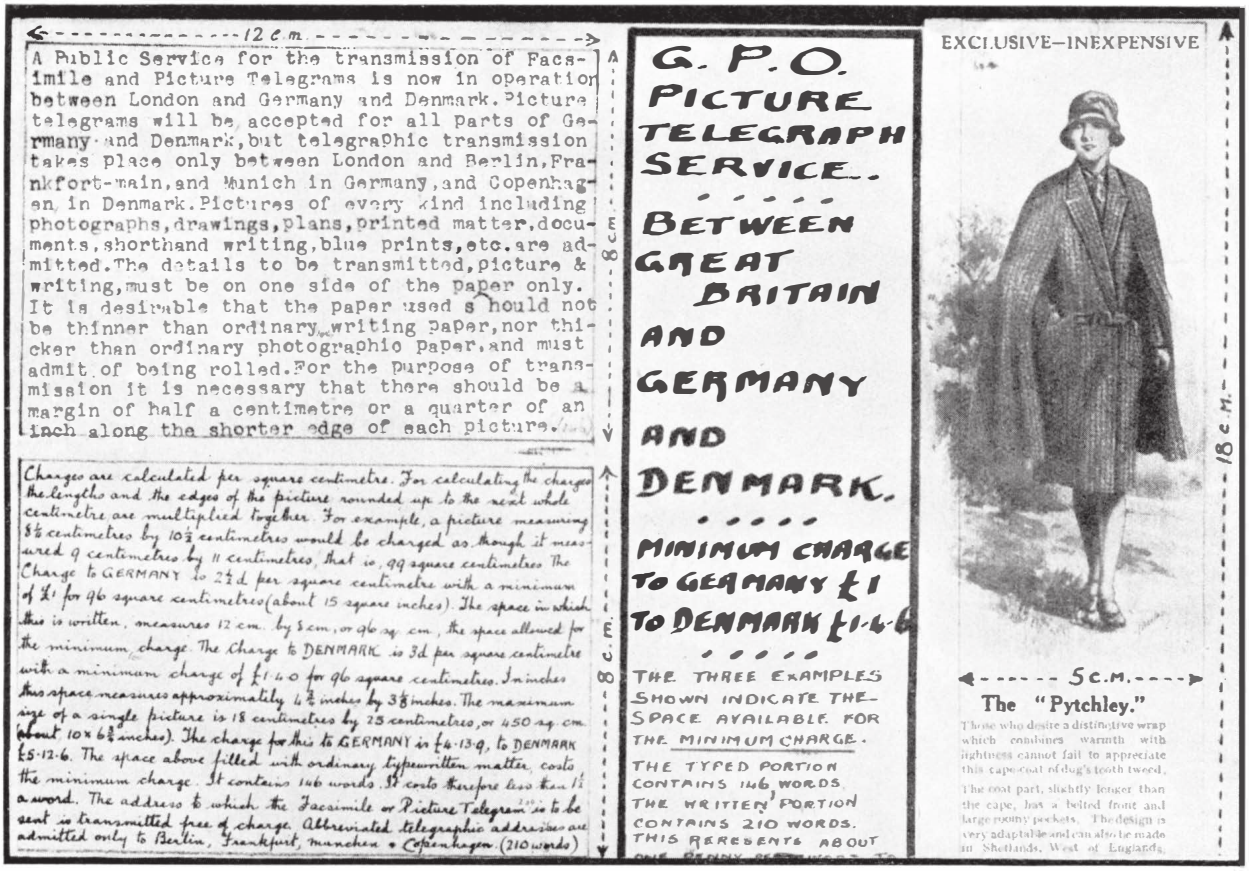

12 c.m.
A Public Service for the transmission of Facsimile and Picture Telegrams is now in operation between London and Germany and Denmark. Picture telegrams will be accepted for all parts of Germany and Denmark, but telegraphic transmission takes place only between London and Berlin, Frankfort-main, and Munich in Germany, and Copenhagen in Denmark. Pictures of every kind including photographs, drawings, plans, printed matter, documents, shorthand writing, blue prints, etc. are admitted. The details to be transmitted, picture & writing, must be on one side of the paper only. It is desirable that the paper used should not be thinner than ordinary writing paper, nor thicker than ordinary photographic paper, and must admit of being rolled. For the purpose of transmission it is necessary that there should be a margin of half a centimetre or a quarter of an inch along the shorter edge of each picture.
8 c.m.
Charges are calculated per square centimetre. For calculating the charges the lengths and the edges of the picture rounded up to the next whole centimetre are multiplied together. For example, a picture measuring 8½ centimetres by 10½ centimetres would be charged as though it measured 9 centimetres by 11 centimetres, that is, 99 square centimetres. The Charge to GERMANY is 2½d per square centimetre with a minimum of £1 for 96 square centimetres (about 15 square inches). The space in which this is written, measures 12 cm. by 8 cm., or 96 sq. cm., the space allowed for the minimum charge. The charge to DENMARK is 3d per square centimetre with a minimum charge of £1 4 0 for 96 square centimetres. In inches this space measures approximately 4¾ inches by 3⅛ inches. The maximum size of a single picture is 18 centimetres by 25 centimetres, or 450 sq. cm. (about 10 x 6¾ inches). The charge for this to GERMANY is £4-13-9, to DENMARK £5-12-6. The space above filled with ordinary typewritten matter, costs the minimum charge. It contains 146 words. It costs therefore less than 1½ a word. The address to which the Facsimile or Picture Telegram is to be sent is transmitted free of charge. Abbreviated telegraphic addresses are admitted only to Berlin, Frankfurt, München & Copenhagen. (210 words)
8 c.m.
G. P. O. PICTURE TELEGRAPH SERVICE.
BETWEEN GREAT BRITAIN AND GERMANY AND DENMARK.
MINIMUM CHARGE TO GERMANY £1 TO DENMARK £1-4-6
THE THREE EXAMPLES SHOWN INDICATE THE SPACE AVAILABLE FOR THE MINIMUM CHARGE.
THE TYPED PORTION CONTAINS 146 WORDS. THE WRITTEN PORTION CONTAINS 210 WORDS. THIS REPRESENTS ABOUT
EXCLUSIVE—INEXPENSIVE
18 c.m.
5 c.m.
The "Pytchley."
Those who desire a distinctive wrap which combines warmth with lightness cannot fail to appreciate this cape-coat of dog's tooth tweed.
The coat part, slightly longer than the cape, has a belted front and large roomy pockets. The design is very adaptable and can also be made in Shetlands, West of Englands,

FIG. 8.—SPECIMEN OF RECEPTION, INDICATING POSSIBILITIES OF SERVICE.

(2) Printing either by enlarger or contact	3	minutes.
Developing	2	,,
Fixing	1	,,
Washing	2	,,
Hardening	10	,,
Glazing		
Drying		
Extras, etc.	3	,,
Total	21	,,

Celerity is the chief factor in the production of these films and prints, and consequently permanency is not closely studied. Nevertheless, films and prints made two years ago under similar conditions during the experimental trial of the system do not show any signs of deterioration. Samples of experimental work are shown in Figs. **6**, **7** and **8**.

MANCHESTER AUTOMATIC TELEPHONE SYSTEM.

RECENT DEVELOPMENTS.

L. F. MORICE, A.M.I.E.E.

A PRELIMINARY article on the Manchester Automatic Telephone System was published in this Journal in January, 1928, and a further article, describing the construction of the new underground plant in Manchester, appeared in January, 1930. Certain additions and alterations to the arrangements described in the preliminary article have since been decided upon and, as the three first automatic exchanges in the area have recently been brought into use, the opportunity is now taken of bringing the information up to date, and furnishing a brief summary of the more important changes that have taken place, together with the various considerations which have led to their adoption.

Exchanges opened.

The first stage of the Manchester programme was duly accomplished on June 7th, 1930, when the following automatic exchanges were opened for service :—

Name of Exchange.	Installed by	Capacity of Subscribers Multiple.	
		Initial.	Ultimate.
Ardwick	Siemens Bros. & Co., Ltd.	3400	5500
Collyhurst	Standard Telephones & Cables, Ltd.	2100	3500
Moss Side	General Electric Co.	1900	2900

Auto Manual Board.

The auto manual equipment necessary to provide Toll, Enquiry, and other auxiliary manual facilities for these three exchanges was also brought into use at the same time.

This equipment forms an advance portion of the main auto manual switchboard for the area, which is being installed at Telephone House, Chapel Street, Salford, by Messrs. The Automatic Telephone Manufacturing Co., Ltd., of Liverpool. The magnitude of this equipment will be appreciated by reference to the following schedule :—

Type of Position.	No. of Positions required at		
	Opening Date.	Main Transfer (1931)	Ultimately (1951)
"B" Positions.			
Key-Sending (7-Digit)	—	18	22
Key-Sending (4-Digit)	10	22	—
Plug-Ended	—	12	15
"A" Positions.			
Toll	33	102	287
Enquiry	10	63	117
Service P.B.X.	—	6	11
Totals	53	223	452

Fig. **1** shows the lay-out of these positions in the manual switchroom, which is reputed to be the largest in the world. Figs. **2** and **3** are views

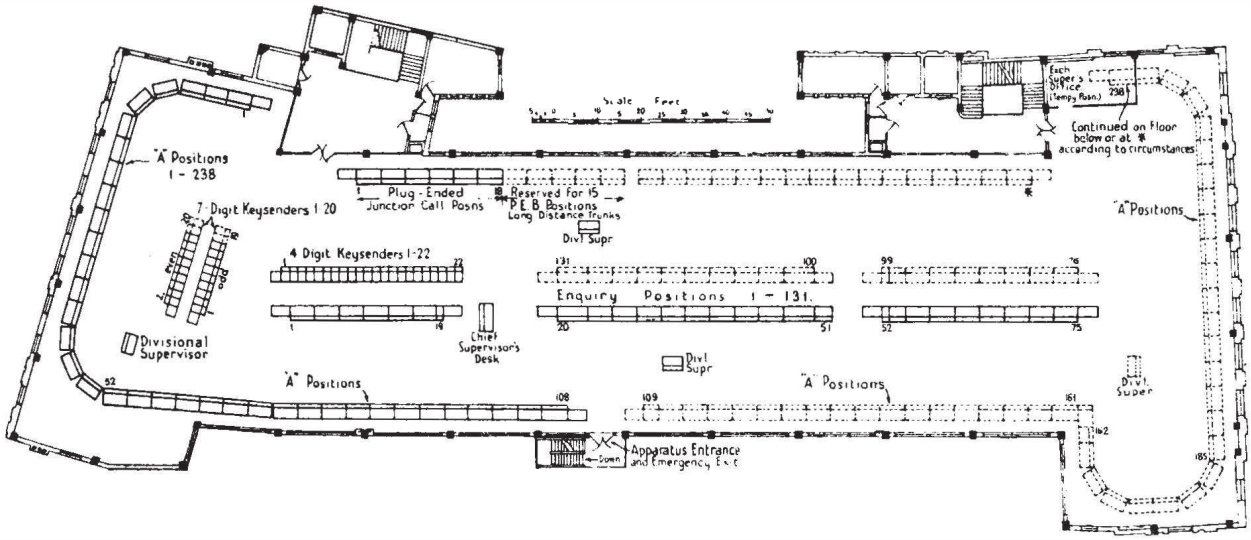


FIG. 1.—MANUAL SWITCHROOM, LAY-OUT PLAN.

of a portion of this room. The Enquiry positions are on the right hand side and the Toll suite on the left. In the far centre of Fig. **2** is the Divisional Supervisor's Desk No. 1, on the top of which will be seen the traffic recorders. These are actually ammeters, calibrated to indicate the number of calls awaiting attention at any instant on the 4-digit or 7-digit key-sending positions respectively. In the near centre of Fig. **3** will be seen the Divisional Supervisor's Desk No. 2.

Manchester claims to be the focal centre of the largest industrial area in the British Empire and,

FIG. 2.—VIEW OF MANUAL SWITCHROOM.

FIG. 3.—ANOTHER VIEW OF MANUAL SWITCHROOM.

as all Toll traffic for the Automatic Area—except for a small proportion which will be handled at Ashton and Main (Oldham) manual centres—will have to be dealt with at this switchboard, the number of junctions (over 3,000 ultimately) in the outgoing junction multiple is unusually large for an exchange associated with automatic equipment. It has been found necessary therefore to introduce special features in the design of this equipment. Special 3 position, 8 panel sections of the C.B.1 type have been designed to meet the requirements of this and similar provincial director Areas. The multiple extends over six panels. " Visual Engaged " signals have been abandoned, owing to the heavy drain on the battery which would result from their use in an exchange of this size.

In place of these signals a system of " first choice testing " has been introduced for all large outgoing groups. For this purpose such a group will be used as first choices, one or more circuits in this portion being allotted as first choices at each appearance of the multiple. The right hand portion is known as the " pool." The whole of the circuits are available to each operator, who will, however, test them in the following order:—

(*a*) First choice circuits for her particular section of the multiple.
(*b*) The " pool."
(*c*) First choice circuits for other sections of the multiple.

The jacks of the circuits in group (*a*) and the first jack in group (*b*) are suitably marked to assist the operators.

Each five circuits will have a tone superimposed on the click test when all the five circuits are in use. Operators can therefore rapidly test the groups and, on finding an idle group, will test the individual jacks in the group. It has been estimated that, by adopting this scheme, the number of tests made per operator will be reduced by as much as 50% where very large groups are concerned.

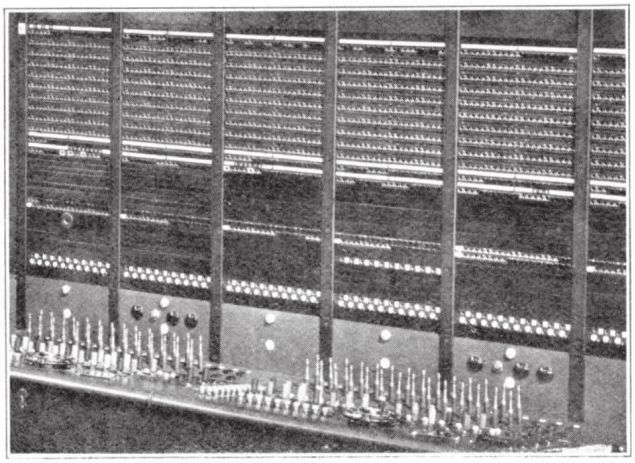


FIG. 4.—TOLL POSITIONS (DIAL TOL).

Fig. 4 is a view of a Toll position, and Fig. 5 shows the Plug-Ended "B" positions. A Key-Sending 7-Digit position appears in Fig. 6. The 4-Digit position is similar, except that the digit key designation strip engraved with the code letters is not provided. The Enquiry positions, which are partly 8-panel and partly 6-panel sections, are shown in Fig. 7.

Area Conversion Programme.

The first 10,000 line automatic exchange in the Chapel Street building, to be known as Blackfriars, is at present under construction by Messrs. The Automatic Telephone Manufacturing Co., Ltd., and will probably be ready for service during next year. The remaining automatic exchanges in the area will be opened at various dates within a period of about 15 years, the exact date in each case being determined by the condition of the existing manual plant and the growth in the number of subscribers' lines.

The total number of exchanges in the area for which design is proceeding is now 36, as the Hyde Exchange, being situated outside the seven mile radius from Manchester Town Hall, has been excluded from the scheme.

Coder Call Indicator (C.C.I.) Equipment.

Eight positions at the City and Central manual exchanges have been equipped with C.C.I. apparatus, for dealing with calls from the automatic exchanges. This equipment has also been supplied by the Automatic Telephone Manufac-

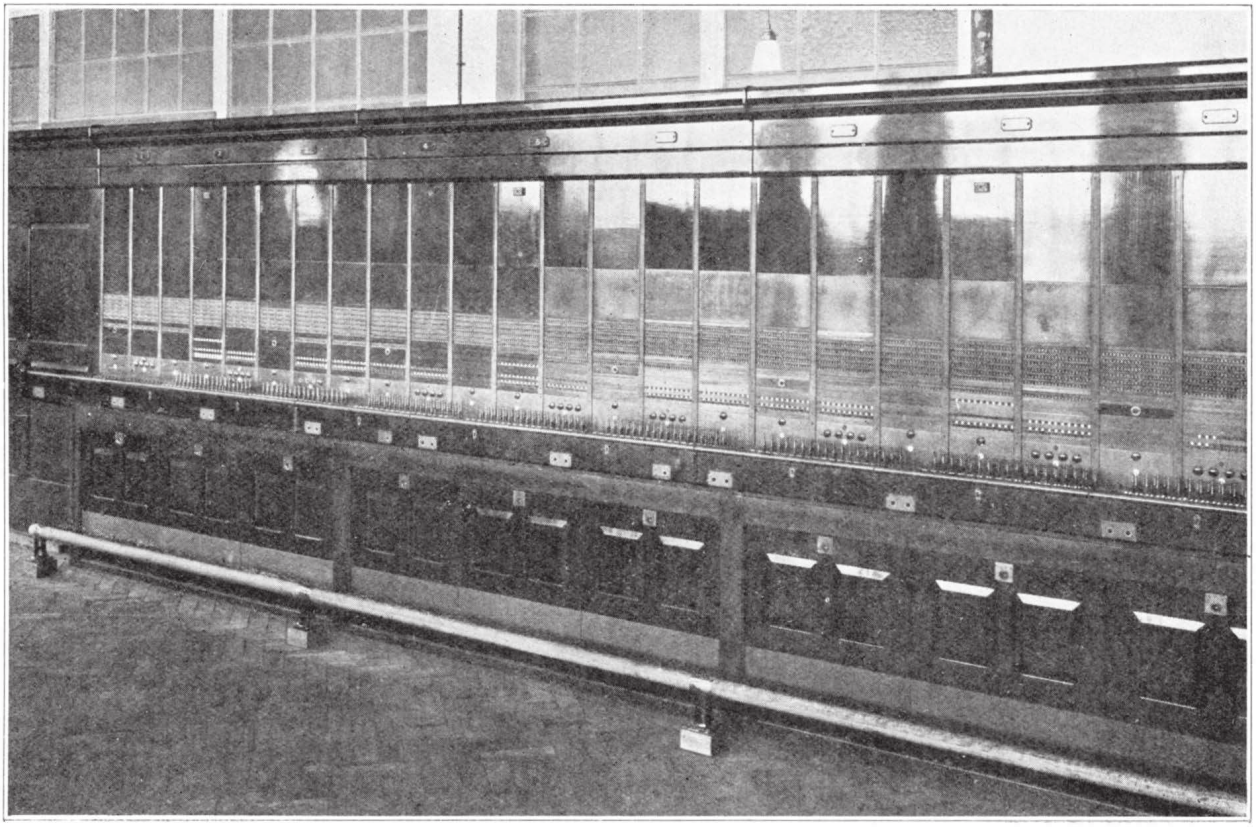


FIG. 5.—PLUG-ENDED "B" POSITIONS.

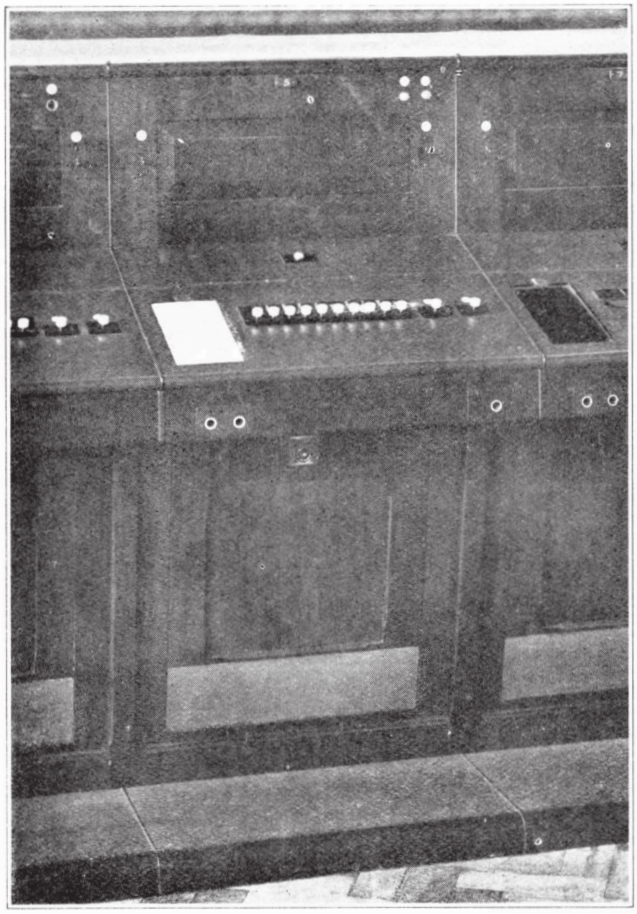


FIG. 6.—KEY SENDING (7-DIGIT) " B " POSITION.

turing Co., Ltd. A number of C.B. and C.B.S. Exchanges, which are to be retained in service for some years, will be similarly equipped some time in 1931. In the meantime the automatic subscribers will obtain connections to all manual

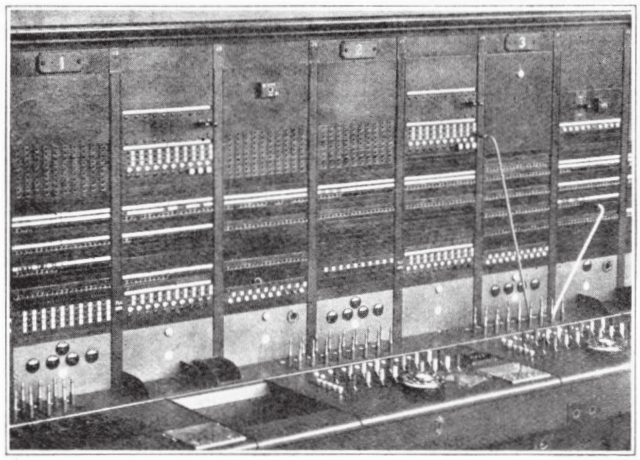


FIG. 7.—ENQUIRY POSITIONS (DIAL O).

exchanges, other than City and Central, *via* the new Toll exchange, by dialling TOL.

Straightforward Junction System.

The method of operating " B " positions known as " order wire key sending," which is now in use at the London Tandem and automatic exchanges, is to be replaced by a new method known as " straightforward junction working." The new system, which has been devised by the Department's engineers, has been tried out experimentally at the London Tandem exchange and a detailed description will no doubt be given at some future date. This constitutes an important step forward in the method of handling traffic over groups of junctions from manual exchanges. By its means, any one of a group of junction circuits between two exchanges, on being taken into use by an " A " operator at the originating exchange, is automatically connected to a disengaged " B " operator's telephone set at the distant exchange or tandem centre. The junction circuit is then used temporarily as an order wire, so that the provision of a separate pair of wires for this purpose is obviated. As soon as the " B " operator extends the junction circuit to the line required, her telephone circuit is released from the junction and is then available for the receipt of another call. The control of the call throughout is vested in the " A " operator who originates it.

Provided the junctions are not repeatered circuits, or side circuits of phantom loaded conductors, it is possible to deal with small or large groups of incoming or both way lines for through or terminating traffic from C.B., C.B.S., Magneto, or Trunk exchanges by this means, and very considerable economies may therefore be effected. In Manchester, for example, the jack-ended " B " positions have been dispensed with and the whole of the traffic at the " B " end is dealt with by one or other of three groups of operators as follows:—

Terminating calls are dealt with by operators at the Key-Sending 4-digit positions.

Through calls for various automatic and C.C.I. manual exchanges in the automatic area are handled at Key-Sending 7-digit positions.

Through calls for Non-C.C.I. manual ex-

changes in the automatic area, and for all exchanges outside this area, are received at the Plug-Ended " B " positions.

The Key-Sending operator is only associated for the purpose of setting up the automatic call, whilst the operator at a plug-ended " B " position has not only to complete the connection but also to clear same at the termination of the conversation. In either case, however, the " B " operator is only in circuit for the short period necessary to complete the connection, hence a substantial saving in " B " operators has been found possible. The calls are received at the operators' positions in cyclic order, and positions in each of the three groups can be shut down and rendered engaged by merely withdrawing the operator's instrument plug in the usual manner. The calls are then automatically distributed to the remaining (staffed) positions.

It will be seen that this new method of operating junction groups has the following advantages :—

(*a*) Order - wire operating facilities are afforded without the provision of a special order-wire circuit. It becomes economical therefore to adopt this method of working for the smallest groups of junctions.

(*b*) For the reasons stated in (*a*) the bulk of the incoming junction traffic from manual exchanges can be automatically concentrated on suites of Key-Sending or Plug-Ended " B " positions, and the less rapid " signalling junction " method is therefore eliminated.

(*c*) Since the " B " operator has not to assign a junction the possibility of error, which existed under the older system, is avoided and operating time, both at the " A " and " B " ends, is reduced. This should result in an increase in the load possible per " A " and " B " position, and a consequent reduction in the number of these positions required.

(*d*) Only one " A " operator is connected to the " B " operator's telephone circuit at any given moment. The interruptions which are apt to occur on a common order-wire circuit are thus avoided.

It is not intended however to convey the impression that this system represents the high water mark in manual methods of junction operation. A system for keysending from " A " positions is now under trial, and this has the further advantage of completely eliminating " B " operators so far as calls to automatic or C.C.I. exchanges are concerned. There will still be a field, however, for the straightforward junction method of working for calls to manual (non-C.C.I.) exchanges *via* the Tandem Centre in an area such as Manchester.

Some idea of the saving effected by the straightforward junction scheme will be gained by reference to the following comparative requirements for the Manchester case for the period 1931 to 1936, under the two methods of operating :—

Item.	Order Wire "B" Scheme.	Straight-forward Junction Scheme.
	No.	No.
Junction Circuits, incoming and bothway.		
Long Distance plug - ended Junctions	73	—
Order-Wire Junctions ...	1115	—
Order-Wires	69	—
Incoming Signal Junctions ...	96	—
Bothway Signal Junctions ...	54	—
Incoming to Auto (Key-Sending)	—	336
Incoming to Manual (Plug Ended)	—	250
Incoming to Auto or Manual (Key-Sending or Plug-Ended)	—	520
Bothway to Auto or Manual (Key-Sending or Plug-Ended)	—	111
Totals	1307	1217
Operators' positions.		
Jack-Ended " B "	12	—
Plug-Ended " B " (without key-senders)	7	12
Plug-Ended " B " (with key-senders)	33	—
Key-Sending (7-digit)... ...	—	18
Key-Sending (4-digit)... ...	24	22
Totals	76	52
First code selectors for key-sending groups.	(33×36) =1188	666

It will be observed that 90 junction circuits, 24 " B " positions and 520 first code selectors are saved at the initial period, and somewhat larger savings will be effected at the ultimate date.

The 7-digit key-sending and the plug-ended " B " equipment will not be available until some time in 1931, but the 4-digit key-sending positions were brought into use in connection with the opening of the first three automatic exchanges. All traffic from City, Central, and a number of other manual exchanges (from which separate groups are justifiable) to Ardwick, Collyhurst, and Moss Side automatic exchanges, is dealt with at these 4-digit positions.

The application of the scheme will be readily understood by reference to Figs. **8** and **9** and the following notes:—

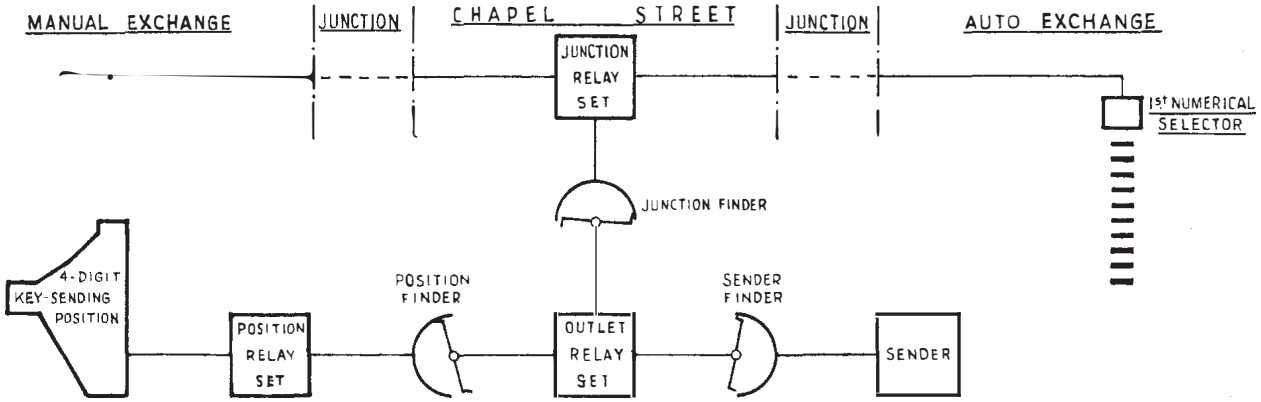


FIG. 8.—DIAGRAM SHOWING " STRAIGHTFORWARD JUNCTION " SYSTEM (TERMINATING CALLS).

Terminating Calls. (See Fig. **8**).

Consider a call from Central Exchange to an Ardwick subscriber. The Central operator will test the outgoing Ardwick junction group in the ordinary way and, on finding a disengaged circuit, will insert the calling plug into the outgoing jack. The supervisory lamp associated with the calling plug will then glow. The junction relay set at the Chapel Street end will then cause a junction finder to search and, having

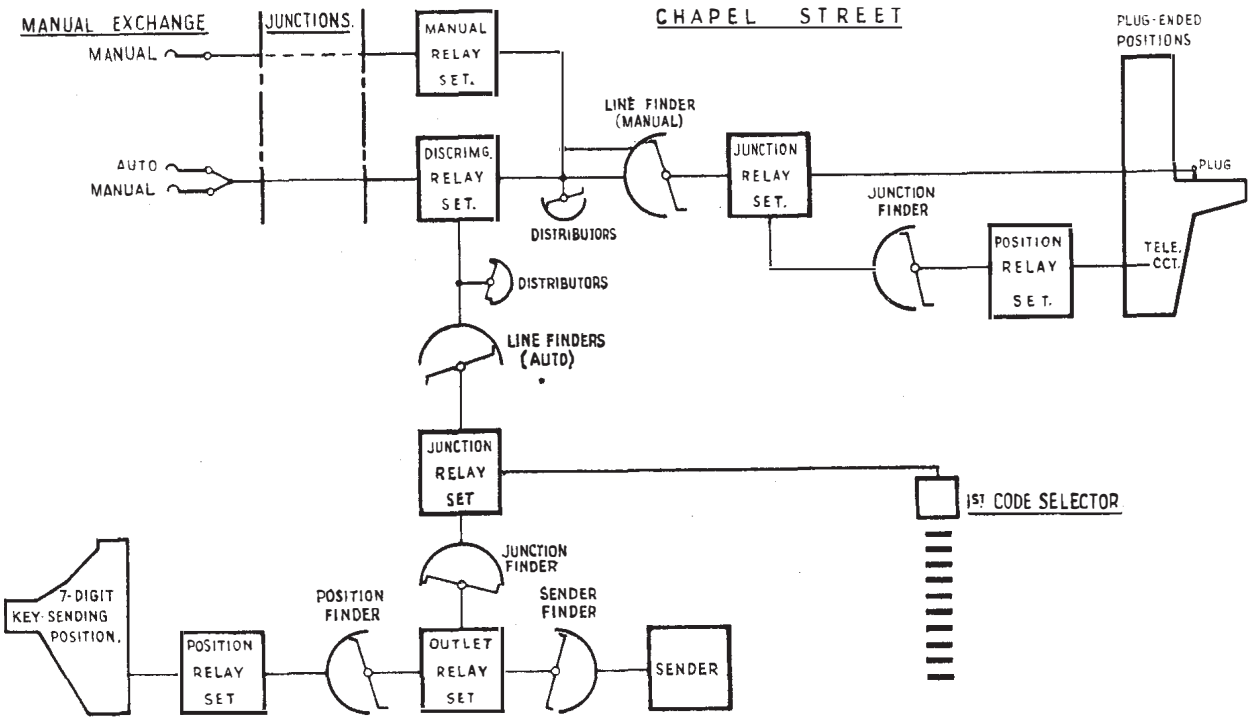


FIG. 9.—DIAGRAM SHOWING " STRAIGHTFORWARD JUNCTION " SYSTEM (THROUGH CALLS).

found the calling junction, to connect the latter to an outlet relay set. Associated with the outlet relay set are two other finders, one of which finds a sender and the other a 4-digit key-sending position. The sender finder hunts simultaneously with the junction finder, but the sender finder switching relay does not operate until the junction finder switching relay has operated, thus preventing the unnecessary holding of a sender. By this means the sender is generally preselected, and will be connected up immediately the junction finder seizes the junction relay set. As soon as the sender is connected up, the position finder searches for a disengaged key-sending operator. When the latter is found and connected up, a lamp lights at the key-sending position to warn the " B " operator that an order is about to be given. The supervisory lamp at the " A " position is extinguished, also a " pip pip " tone signal (400 p.p.s.) is returned to the " A " operator at Central to advise her that a key-sending operator awaits her demand. The " A " operator thereupon states the number required, *e.g.*, 2345, and the key-sending operator keys this up immediately. When the last digit key is depressed the lamp on the key-sending position is extinguished, and the position becomes dissociated from the junction and ready for the next demand. Also the supervisory lamp at the " A " position relights until the called subscriber answers.

The Sender, Sender Finder, Position Finder, Junction Finder and Outlet Relay Set all remain associated with the junction until the train of impulses corresponding to the last digit has been sent out by the sender, when they are all released and become available for another call. The Junction Relay Set, which contains the transmission element, remains in circuit until the end of the conversation.

There are many interesting points in connection with the grouping of the relay sets and the various finders, but these hardly come within the scope of this article and must await the fuller description of the scheme referred to above.

Through Calls.

A 7-digit *automatic* call would be dealt with in a similar fashion to that described above for terminating calls, except that 7-digit senders and key-sending positions are required. Also, as such calls will generally be originated over junctions on which the through *manual* traffic will require to be routed, a discriminating relay set will be necessary. The scheme for through calls is indicated in Fig. **9**. It will be seen that this caters for both kinds of junction circuits, viz. :—

(*a*) Circuits incoming for through manual calls only.

(*b*) Circuits incoming for through manual or automatic calls.

In case (*a*) the originating " A " operator, on plugging into the jack of a free outgoing junction, engages the relevant manual relay set. This causes the line finder to search and, having found the calling circuit, to connect the latter to a free junction relay set. The latter is associated with a particular plug-ended cord, and the calling lamp associated with this cord glows until the " B " operator has completed her previous call. When this has taken place the junction finder will search and, on finding the calling circuit, will connect it to the " B " operator's telephone set. As soon as the latter is connected, the calling lamp associated with the plug-ended cord will flash, to indicate to the " B " operator the cord of the junction over which the next demand will be received. The supervisory lamp on the " A " position is extinguished, and a " pip pip " tone signal (400 p.p.s.) is returned to the " A " operator, advising her that a " B " operator awaits her demand. The " A " operator states the exchange concerned, and the " B " operator completes the connection *via* the outgoing junction multiple. As soon as this is done the supervisory lamp on the " A " position relights, the calling lamp on the " B " position is extinguished, and the " B " operator's telephone set is released and made available to deal with the next call. Arrangements have been made to allow a maximum of three calls to be waiting at any one moment at any position.

In case (*b*) there are two jacks in the outgoing junction multiple at the manual exchange, one for calls to automatic and C.C.I. exchanges, and the other for calls to manual exchanges. If the " A " operator plugs into the *manual* jack, the discriminating relay set allows the associated *manual* junction relay set to be taken into use, and the call proceeds as described in case (*a*). If, on the other hand, the operator plugs into the

auto jack, the discriminating relay set allows the *auto* junction relay set to be appropriated, and the call proceeds as described for the 4-digit (terminating) calls. In this case, however, a 7-digit sender and key-sending position will be associated for the purpose of setting up the call.

Multiple Fee Calls, Automatic Registration.

Calls between exchanges in the Manchester multi-exchange area (which comprises the area within a radius of 7 miles from the Manchester Town Hall) will be charged at 1d., 2d. or 3d., according to the radial distances concerned.

Hitherto it has been contemplated that it would be necessary to divert all 2d. and 3d. calls to the manual board, in order that these might be recorded and the appropriate junction fee debited to the subscriber's account in due course. Schemes have now been devised, however, by the Department's engineers under which the subscriber's meter will be operated twice on 2d. calls and thrice on 3d. calls, thus avoiding the necessity for the intervention of an operator.

The first scheme (called for convenience the " Director Translation " method) and the one to be adopted at Manchester Exchanges, is briefly as follows :—

The code digits sent into the Director are translated into one " fee discriminating " digit followed by 1 to 5 " routing " digits, instead of the usual 1 to 6 " routing " digits only. Each 1st code selector is provided with a special vertical marking bank and wipers, associated with which are two discriminating relays. A slight change is also necessary in the code selector circuit proper. The fee discriminating digits may, for example, be 1, 2 and 3. On receipt of the first train of impulses the first code selector will therefore rise to Level 1, 2 or 3. If to Level 1, one of the discriminating relays is operated, and the circuit is then prepared for *unit* fee registration. If to Level 2, the other discriminating relay is operated, and the circuit is then prepared for *double* fee registration. If to Level 3, both discriminating relays are operated, and the circuit is prepared for *triple* fee registration. Quadruple or quintuple fees could be arranged for, if necessary, by similar means. The multiple operation of the meters is produced by cams mounted on a special slow speed interrupter. At the end of the first train of impulses, the circuit for the release magnet is closed, and the first code selector restores to normal, but the circuit modifications are such that the closing of the rotary magnet circuit is delayed until the end of the second train of impulses. The second and succeeding trains of impulses (which represent the " routing " digits) are received by the code selectors, which then function in the normal manner. It will be appreciated that this scheme, with the Director system as at present designed, reduces from six to five the possible number of switchings for routing purposes. This however is not likely to be a disadvantage in the Manchester area, where the largest number of such switchings visualised at present is four. This scheme, whilst being simple and comparatively inexpensive for new exchanges, cannot be introduced very easily at large exchanges which have been brought into use already without the multiple fee registration facility, inasmuch as the accommodation of the special relays, the modification of the first code selector circuit, and the simultaneous rearrangement of all the director translations in such an exchange, would present practical difficulties of a serious character.

With a view to catering for such cases, another scheme has been devised. With the latter scheme (called for convenience the " 1st Code Selector Level " method) the special vertical bank is still required, and its wiper connects the meter wire direct to the appropriate multiple metering cams. No discriminating relay set is required, and no other change is necessary in the first code selector circuit. On the other hand, each class of fee must be allotted a separate first code selector level. The level to which the first code selector is raised by the first train of translated code digits will determine whether the subscriber's meter will receive one, two or three impulses when the registration of the call is effected.

With this scheme, calls routed *via* Tandem would require a maximum of three levels, one for 1d. calls, one for 2d., and one for 3d. The outlets from all levels allotted for Tandem traffic, however, would be graded in one common group, the segregation of levels being necessary for multiple metering purposes only. If sub-Tandem Centres should eventually be found economical it would, of course, be necessary to

allot a maximum of three levels for each such Centre. Multiple fees for calls to exchanges reached direct must also be given first code levels. The restriction in the trunking which results from the use of this scheme will be appreciated by a comparison of Figs. **10** and **11**, which

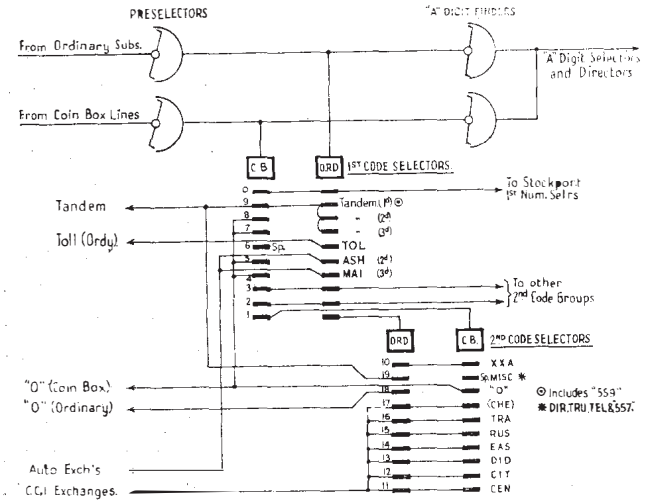


FIG. **10**.—DIAGRAM SHOWING STOCKPORT TRUNKING (WITH DIRECTOR TRANSLATION METHOD OF MULTIPLE FEE REGISTRATION).

show the trunking arrangements which would obtain at Stockport exchange. In Fig. **11** (the first code selector level scheme) the first code selector levels 4 and 5 are allotted to MAI and ASH, (multiple fee direct routes) respectively, and levels 7, 8 and 9 to Tandem traffic. The traffic for BLA, DEA, and CEN, however, which is individually heavier than for Tandem,

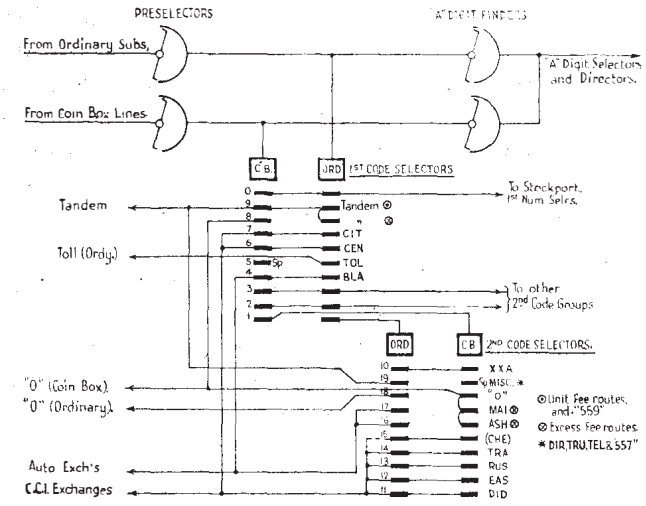


FIG. **11**.—DIAGRAM SHOWING STOCKPORT TRUNKING (WITH 1ST CODE SELECTOR LEVEL OF MULTIPLE FEE REGISTRATION).

MAI, and ASH, must all be routed *via* second code levels. More second code selectors will therefore be required than with the Director Translation scheme seen in Fig. **10**.

It will be appreciated that difficulties will be encountered in applying even this scheme at existing exchanges in some cases, and other schemes are under consideration to enable the facility to be provided under all circumstances without undue circuit complexity or expense.

The Director Translation scheme has been adopted for Manchester in view of the greater trunking facilities afforded thereby, the maximum of five switchings available for routing purposes being ample in this Area, as before mentioned.

Coin Box Multiple Fees.

Multiple fee calls from coin box subscribers, however, must still be routed to the manual board, to enable an operator to supervise the insertion of the appropriate fee in the coin box. This is the reason why in Fig. **10** two levels have been allotted for Tandem traffic, level 9 being for unit fee calls, whilst multiple fee calls will pass *via* level 8. Further, any calls over direct routes on which more than the unit fee is chargeable must be similarly segregated. MAI and ASH are the only direct multiple fee routes in this particular exchange.

The total number of multiple fee calls from coin box lines at any exchange is usually very small, and would not as a rule justify a separate group of junction circuits to the manual board. A separate group of Coin Box " O " circuits (terminating at the Toll positions) will, however, be provided for each exchange, and advantage is taken of that fact to pass the multiple fee calls from coin box lines to the Toll positions *via* the same group of circuits. In Fig. **10** therefore coin box levels 8, 17 and 16 are commoned with level 18. Similarly in Fig. **11** levels 4, 5, 7 and 8 are commoned with level 18.

Satellite Working.

The introduction of these schemes for auto-registration of multiple fees has limited considerably the field for satellite working in director areas.

In the first place a third wire is required on each junction outgoing from the satellite to the

parent exchange, and this of course modifies the financial aspect very materially.

In the second place, the junction fees will rarely be the same for any two exchanges in an area. Hence, if the economic advantage of a common group of directors for the parent and its satellites is to be retained, a difficulty at once arises, whichever of the two schemes of automatic registration is adopted. [If a common group of directors is not retained the economic advantage of satellite working would generally disappear and it would become cheaper to provide directors at each exchange, thus avoiding the heavy expense of the discriminating equipment at the satellites]. The difficulty will be appreciated more clearly by considering a particular case. For this purpose, assume that Prestwich exchange is to function as a parent exchange for two satellites, Radcliffe and Whitefield. In this case it so happens that there are no multiple fee calls which would be routed direct, all such calls being more economically passed *via* Tandem. An examination of the Tandem routes reveals five distinct combinations of fees for the three exchanges as follows:—

Group.	To Exchanges.	Fee for call from		
		PRE	RAD	WHI
1	ECC, MOS, RUS, WAL, WHI.	1d.	1d.	1d.
2	CHO, EAS, MID.	1d.	2d.	1d.
3	DID, DRO, FAI, HEA, LON, SAL, URM.	1d.	2d.	2d.
4	DEN.	2d.	3d.	2d.
5	ASH, GAT, MAI, STO, WOO.	2d.	3d.	3d.

Now, since the same translation must apply for any given exchange code, from whichever of the three exchanges the call originates, the first train of impulses must be different for each of these five groups. With the first code selector level method, this would require five separate first code levels for Tandem traffic (as shown in Fig. **12**). With the director translation method, five levels of the special marking bank would have to be allotted.

Further fee variations are obviously possible, and would have to be catered for if new exchanges were opened in the area, or if the area were enlarged to embrace 4d. and 5d. routes, in which case further levels would be required.

In view of this limitation it is unlikely that either scheme would be practicable for more than two or three satellites associated with any one parent exchange. The original Manchester proposals, for example, under which 12 satellites were to be dependent on Blackfriars as parent, would be clearly impracticable owing to the large number of fee variations which obtain at the 13 exchanges concerned.

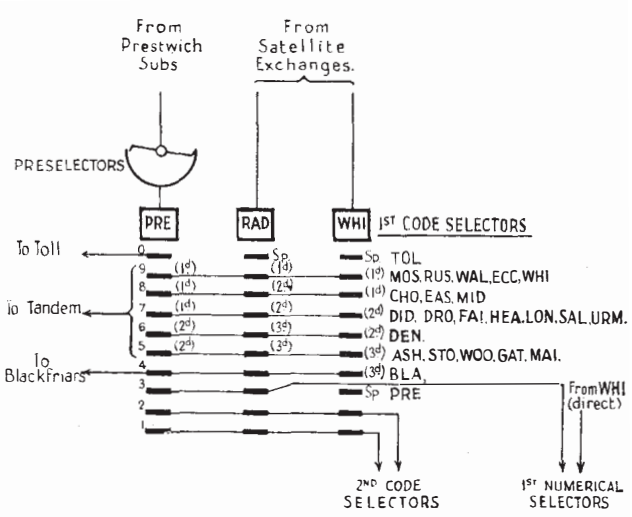


FIG. 12.—DIAGRAM SHOWING PRESTWICH AS PARENT EXCHANGE FOR TWO SATELLITES, RADCLIFFE AND WHITEFIELD.

Moreover, so far as Manchester is concerned, investigations have shown that, on the present lay-out of the area, there is no case where satellite working can be introduced with economy.

In the circumstances, therefore, it has been decided to provide directors at all exchanges in the Manchester area, as now planned. In some of the larger exchanges round the fringe of the seven mile radius, however, it might eventually be found desirable, if development proceeds more rapidly than is at present anticipated, to afford relief by serving a small portion of the area by a satellite exchange, with the existing exchange as its parent.

Speaking generally, however, it seems probable that, unless some other scheme for the auto-registration of multiple fee calls is devised, satellite working in director areas will not be

both practicable and economical for more than two or three satellites associated with any one parent exchange. A necessary condition will also be that the parent and its satellites must not be far apart, so that the number of fee combinations to be catered for will be a minimum.

The abolition of satellite working has resulted in a considerable reduction in the quantity of equipment required at the Blackfriars exchange.

It has also simplified the trunking arrangements at that exchange very considerably, since there is now no necessity for the large number of separate groups of second code switches, which would otherwise have been required in order to segregate the multiple fee traffic.

The restrictions in routing imposed by the discriminating satellite scheme are also avoided thereby, and greater flexibility in junction routing becomes practicable, with consequent economies in line plant costs.

Miscellaneous Traffic from Ordinary Subscribers.

The following codes are used for the types of calls mentioned below :—

DIR for calls to directory enquiry.
TRU for calls to trunk records and trunk enquiry.
TEL for calls to phonograms (for *inland* telegrams).
557 for calls to phonograms (for *foreign* telegrams).
559 for calls to phonograms (*Telephone-Telegram* traffic from Sub Post Offices).

The amount of traffic in each case is very small and does not, as a rule, justify a separate group of junctions to the service point. It is therefore economical to route all these calls *via* the Tandem group from the Sub Exchanges (*e.g.*, See level 19 on Fig. **10** for the Stockport Exchange), and split up the traffic at Blackfriars Exchange as shown in Fig. **13.**

Miscellaneous Traffic from Coin Box Lines.

As is now well known, the code letters of the exchange name shown in the directory for each subscriber's number are printed in capitals when the exchange concerned is automatic or has C.C.I. facilities. Coin box subscribers are instructed to dial " O " for all calls for other exchanges or services.

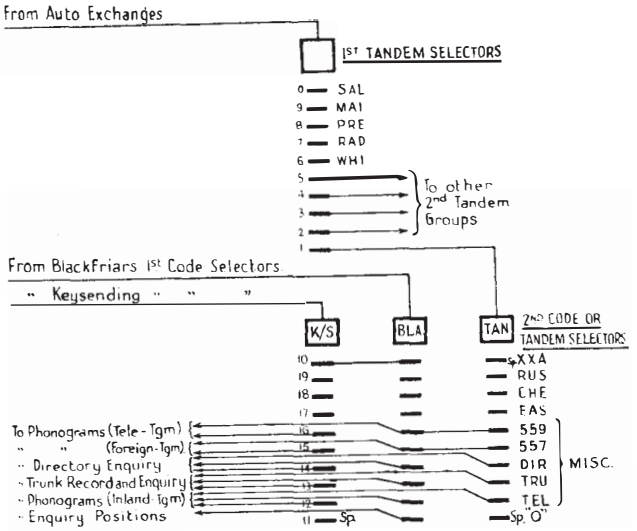


FIG. **13.**—DIAGRAM SHOWING ROUTING OF " MISCELLANEOUS " TRAFFIC FROM SUB-EXCHANGES VIA THE TANDEM SWITCHES AT BLACKFRIARS.

The Coin Box " O " circuits are terminated at the Toll positions, and the " A " operators at these positions have direct transfer circuits to the various service points for disposing of this miscellaneous coin box traffic. Hence, the coin box levels associated with the codes TOL, DIR, TRU, TEL and 557 are connected to the " number unobtainable " (NU) tone (vide levels 6 and 19 in Fig. **10**).

The level for 559 cannot be connected to NU tone, as the circuits for which this service is specially required are frequently from call offices, provided with coin boxes for the use of the general public.

Fig. **14** shows the various types of code level routings which are now necessary to provide the various facilities required in the Manchester Area.

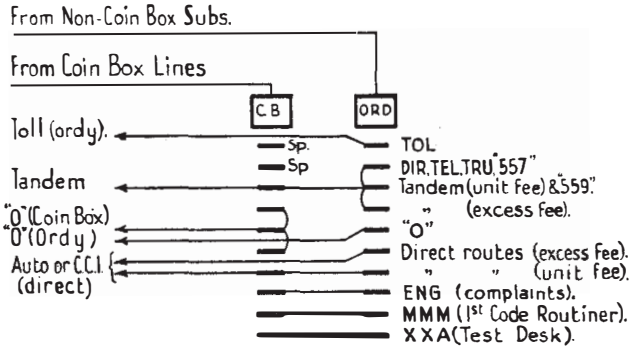


FIG. **14.**—DIAGRAM SHOWING TYPICAL ROUTINGS REQUIRED IN MANCHESTER EXCHANGES.

It might be added that the 3,921 subscribers' lines connected to the three new exchanges were transferred from no less than seven exchanges, and the conversion operation on June 7th was effected without a hitch, and resulted in only eight faults of a minor character. To those acquainted with the multitudinous details and complications inherent to a scheme of this character, it will be obvious that great credit is due to the enginering and traffic staffs concerned for the careful preparatory work necessary to achieve such a successful result.

In submitting these notes, I gladly acknowledge my indebtedness to Mr. A. S. A. Johnson for some suggestions, to Mr. W. E. Hudson for details in regard to the multiple fee registration schemes, and to Mr. W. A. Satchwell, of Manchester, for the photographs shown in Figs. **2-7**.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31ST MARCH, 1930.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
677,635	529	3,965	53,583	128	London	24,898	88,267	2,556,926	95,056
88,825	2,179	21,414	70,144	2,278	S. East	4,035	62,271	244,977	35,122
92,263	4,507	31,729	64,760	3,993	S. West	21,631	16,944	185,098	63,960
74,243	6,277	39,048	67,984	6,477	Eastern	24,529	47,904	156,949	62,731
106,605	8,462	45,229	64,205	4,739	N. Mid.	32,872	63,982	274,084	103,142
91,815	4,852	31,025	79,187	4,286	S. Mid.	12,992	30,162	217,438	81,002
62,383	4,685	29,951	57,404	3,573	S. Wales	6,734	29,306	139,329	69,851
116,140	7,885	26,934	54,771	4,245	N. Wales	13,723	43,655	314,392	60,661
170,122	1,471	15,993	45,156	3,162	S. Lancs.	14,527	84,461	540,287	49,892
101,293	6,098	30,715	49,729	3,344	N. East	14,018	49,329	269,595	72,724
68,926	3,949	24,252	40,660	2,469	N. West	7,754	37,074	177,931	29,427
51,819	2,552	15,998	27,174	2,972	Northern	7,553	21,598	144,866	38,487
23,646	4,490	8,927	14,202	585	Ireland N.	136	2,920	51,741	2,642
71,977	5,386	27,398	41,125	1,193	Scot. East	6,211	17,520	167,816	40,704
04,966	7,254	24,706	45,594	1,064	Scot. West	11,525	27,577	237,117	34,345
1,892,658	70,576	377,284	775,678	44,508	Total	203,138	622,970	5,678,546	839,746
1,854,083	70,779	375,457	762,329	44,696	Figures as at 31 Dec., 1929	202,804	606,348	5,558,868	866,093

AUTOMATIC ROUTINE TESTERS FOR AUTOMATIC EXCHANGES.

W. E. CHINN, A.M.I.E.E., and J. S. YOUNG.

THE opening articles of this series have already been printed in the preceding volume of this Journal, when a general outline of the common functions and operating procedure of Automatic Routiners were given, also the salient circuit features of the First Code Selector, Director and C.C.I. Relay Set Routiners were described.

In this article the functions of the C.C.I. Coder, 4-Digit Sender and Keysending " B " Position Apparatus Routiners will be outlined and points of particular interest will be indicated.

Coder Routiner.—The general design of this routiner is similar to that of the Director Routiner. In the earlier designs the Control Switch functioned entirely for the purpose of controlling the sending of the digits to the Coder under test, while the storage and display apparatus was a replica of the circuit used for the same purpose in the Decoding Relay Groups at C.C.I. Exchanges. In the course of development, however, this design has been altered and the Control Switch is now used for the purpose of both controlling the sending by the routiner and timing the pause between the digits sent to the Coder under test.

Access is obtained to the P, +, − and PU incoming leads to each Coder. The Access Switches are arranged for " Self Drive " over unequipped contacts and under these conditions a relay is operated to delay the commencement of the test cycle. In some of the early equipments no provision is made for the unequipped outlets of the Access Switches and hence should it be necessary to remove a Coder from its position it has to be replaced before routine testing commences, in order that the routiner may not be stopped unnecessarily.

A busy test is applied to the Coder by connecting a relay to the private and closing the operating circuit of a slow-to-operate relay at the same time. Should the private relay operate, it disconnects the circuit of the slow relay before the latter is energised sufficiently to operate and closes the circuit for a delayed alarm. If the private becomes free within a period of 30 to 60 secs. the tests are continued, but otherwise the alarm operates. In some of the later equipments slow-to-operate relays are dispensed with and the circuit is re-arranged in order that slow-to-release relays may be employed instead, while in other equipments the arrangements are the same as mentioned in connection with the C.C.I. Relay Set Routiner, where a double-coil relay is employed for the private test.

In the early types of Coders storage relays are used, but in the standard case these have been replaced by Rotary Switches. The routiners designed for testing the former are arranged to send predetermined digits in such an order that all of the storage relays are tested during each routine; this involves two complete operations of each Coder.

The digits employed were originally 8888 and 4444, but it was found that these allowed certain faults to pass undetected and, in consequence, it was considered desirable to change the order of the digits to 4848 and 8484.

In the standard Routiner, Digit Keys are fitted for the purpose of controlling the digits set up, since in this case it is necessary to be able to test the Coder with any digits.

Relay SS (Fig. 1) operates when the Coder becomes free and causes 10 p.p.s. impulses to be connected to the Sending Switch DM, *via* the magnet impulsing springs. When the Sending Switch steps " off-normal," relay SA operates and removes the short-circuit from across the loop impulsing springs, thus impulsing the Coder *via* contacts of relay A. In the first test, relay SZ operates, after 4 impulses have been sent, and remains operated *via* level 2 of the Control Switch, thus preventing further impulses being sent by short-circuiting the loop impulsing springs. SZ also transfers the magnet impulses to the Control Switch. After 4 steps have been taken by the latter switch, relay SZ is released and the impulses are again directed to the Sending Switch in order that the remaining 3 digits may be sent to the Coder. Relay SC then operates and releases relay SG to prevent further digits being sent.

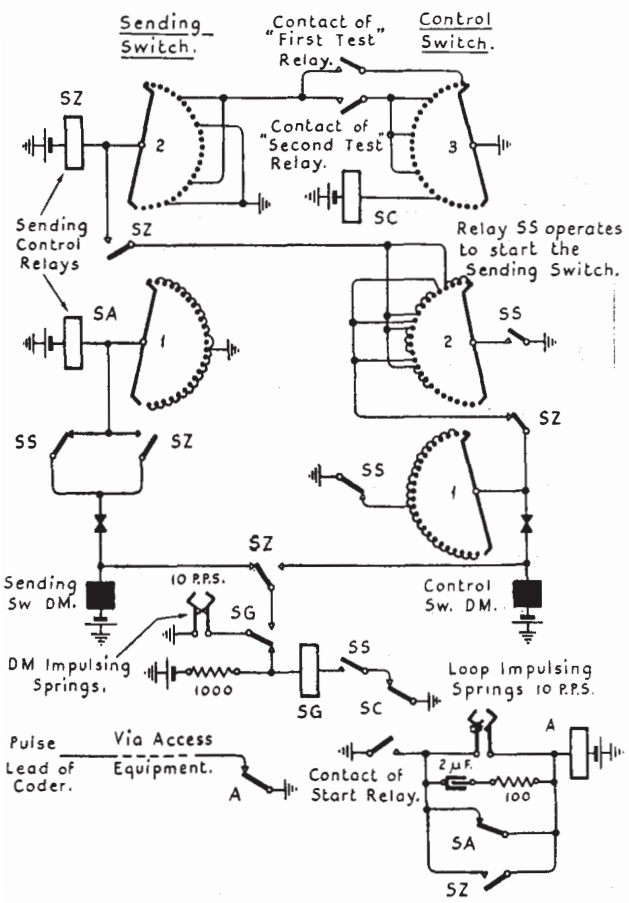


FIG. 1.

During the first test, after the digits have been transmitted, the " sending delay " feature of the Coder is tested by connecting battery and earth to the − and + leads, to hold relay LS for a given time before introducing the decoding loop. Should the Coder commence sending during this period, the routiner is stopped and an alarm is given.

When the decoding loop has been connected the Coder sends out the stored digits. In early routiners these are directed to the routiner display relays by means of two-step relays, and in later equipments by means of a Digit Distributor, the latter being stepped by the operation of a relief relay to the decoding relay LN.

The relief relay is necessary in order that the drive magnet current shall not pass *via* the contacts of the polarised relay, which normally have only 2 mils clearance.

The display lamp connections are taken *via* contacts of the digit keys in a similar manner to that previously described in connection with the Director Routiner. The display is maintained for 3-6 secs.

The private is guarded throughout the tests by connecting to it a low resistance earthed relay, as shown in Fig. **2**. It will be seen that earthing of the private by the Coder under test is detected by the release of this relay.

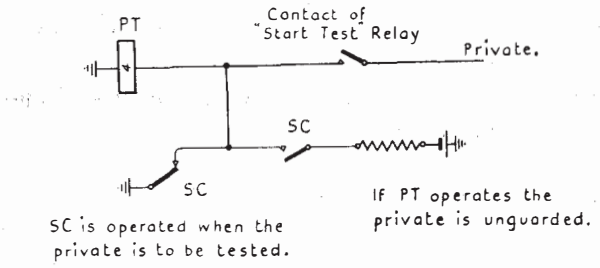


FIG. 2.

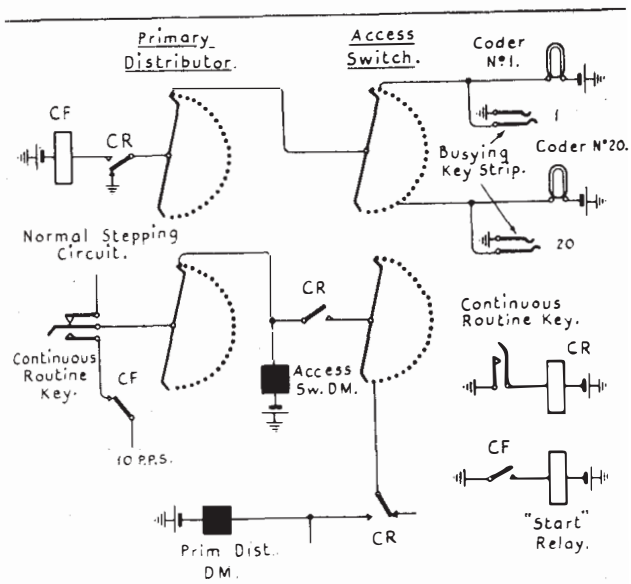


FIG. 3.

During normal routine when the tests on each Coder have been completed the access equipment is stepped to the next Coder.

A special feature has been incorporated in this routiner to facilitate continuous routine testing without the necessity for stepping the Access Switches to the particular Coder. The Coder required is marked by means of a peg inserted into a jack on a busying strip, one of which, together with an indicating lamp, is associated with each Coder, and then on the operation of the Continuous Routine Key, Fig. **3**, 10 p.p.s. impulses are connected to the Access Switch DM. The switch is thus stepped until it reaches the position on which the busying strip is earthed,

when relay CF operates and prevents further stepping and also operates the " Start " relay. When the required Coder is found the routiner commences testing without the necessity for any further operation of keys.

The various delay periods for the display, tests and alarms in the early equipments are provided by means of single time pulse leads and two-step relays. In the later equipments the S and Z alarm scheme is employed.

Fig. 4 shows a typical lay-out of the Coder Routiner equipment.

4-Digit Sender Routiner.—Unlike other apparatus for which auto routiners are provided, the 4-Digit Senders in most Exchanges work entirely in conjunction with local apparatus. The exceptions to this are those provided at the " Parent " Exchanges of " Satellite " areas, where it is general practice to centralise all manual operating positions, and in the Manchester and Birmingham Director areas where all manual boards are being concentrated in one building. In the general case, therefore, " Sender " routiners have been designed to apply functional tests only, there being no variable conditions such as junction resistance, insulation and voltage (other than the normal Exchange voltage variation of from 46-52 volts) to be met with.

The " Access " equipment is fitted on the routiner rack, as in the case of the Director and Coder routiners already described.

In most of the earlier Sender routiners, Test Switches have not been provided, the changes required to the testing conditions having been arranged for by means of relays. In the course of progress, however, it was realised that some economy in apparatus and simplification of the circuit could be made by employing a rotary line switch for measuring the alarm delay periods, which in this routiner are more numerous than in most of the others, and as the result a circuit was designed as shown in Fig. 5. The rotary line switch in this circuit is stepped with interrupted earth pulses, the alarm connections and starting conditions being connected by the relays which are used for applying the particular test in progress. In later circuits this Alarm Switch has been incorporated with the Sending Switch and this combination functions more in the nature of a Test Switch.

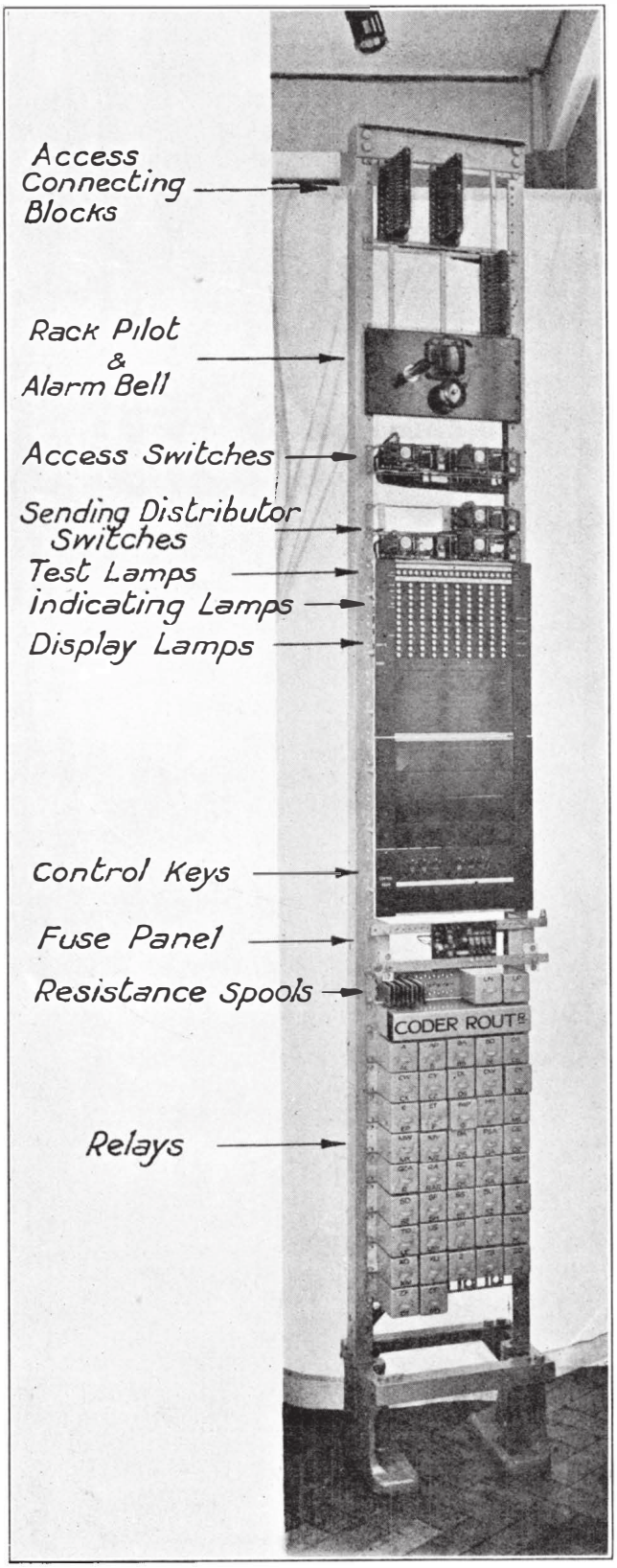


FIG. 4.—CODER ROUTINER.

Facilities are provided for testing the operation of each Sender under normal conditions but, in addition, all the extra features such as " Partial Call," " Manual Board " and " Cancel Condition " may be tested as and when required, these tests being controlled by means of keys.

The operation of the Start Key causes the routiner to step the Distributor and Access equipment to the first outlet associated with a Sender. On arrival of the Access Switch at this outlet the " Private " or " Busy Lead " of the Sender is tested, and, if engaged, the routiner waits until it becomes free or gives an alarm if it is continuously engaged for more than $37\frac{1}{2}$ secs.

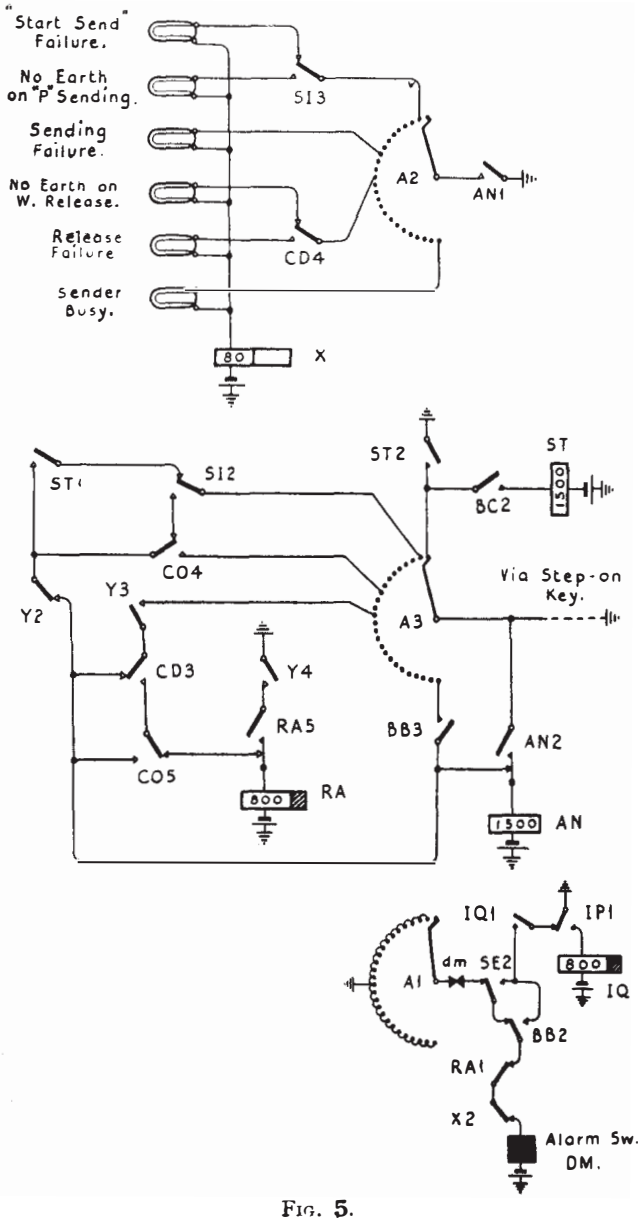


FIG. 5.

This alarm period is measured by the alarm switch. Referring to Fig. **5** relay BB, which tests the private for the engaged condition, starts the Alarm Switch stepping at 40 p.p.m. When the Sender becomes free relay BB releases and " homes " this switch. If, however, relay BB is still operated when the wipers arrive at the 25th contact, relay AN will operate and alarm conditions will be set up.

On the Sender becoming free it is seized in the usual manner by the routiner. The Sending Switch (PS), in the latter (see Fig. **6**) now commences to step under the control of two relays and as the wipers pass over the outlets, digit leads W, X, Y and Z are earthed momentarily in accordance with the code shown in Table I., the digits sent by the routiner being controlled by means of digit keys.

TABLE I.

SHOWING CODE PULSES FOR SENDERS.

Digit.	Storage Relays Operated.
1	W
2	X
3	WX
4	Y
5	Z
6	WZ
7	XZ
8	WXZ
9	YZ
0	XY

When all digits have been sent by the routiner, the " Z " lead is connected *via* contact 12 of bank 4 to the CO relay. The latter relay will only operate when the Sender connects earth to this lead. When CO operates, it closes its locking circuit to the private and, thereafter, depends upon earth being maintained by the Sender. The sending out leads are now connected by CO to the routiner A relay. The translated digits are received by this relay and directed to the relative storing switches. The pause between the receipt of the " Thousands " and the " Hundreds " digits is timed by means of the Pause Timing Switch in a similar manner to that described in connection with the Director routiner.

Should a wrong digit be received, relay XR

will operate in series with the corresponding lamp and normal key contacts and a " Wrong Number " alarm will be given.

When all digits have been correctly received, they are displayed for a period of 2-4 secs., commencing when relay Y operates after the receipt of the last digit. During the release of the Sender, which occurs automatically when all digits have been sent, the private is disconnected and relay CO in the routiner is thereby released.

On satisfactory completion of all tests, the routiner apparatus is restored to normal, the Access Switch is stepped to the next Sender and tests on this proceed in the same manner.

Facilities are provided for setting up 1 digit, then cancelling and subsequently setting up a complete number, these operations being performed in quick succession by the routiner and thereby testing the satisfactory functioning of Senders under cancel conditions. A key is provided in the earlier routiners whereby this feature may be omitted, but in later designs the test is included as part of the normal test cycle.

It is also possible to check all Senders for satisfactory operation under " Partial Call " or " Manual Board " set up conditions; for this test a key is operated which causes the routiner to send an incomplete number. Normally, under

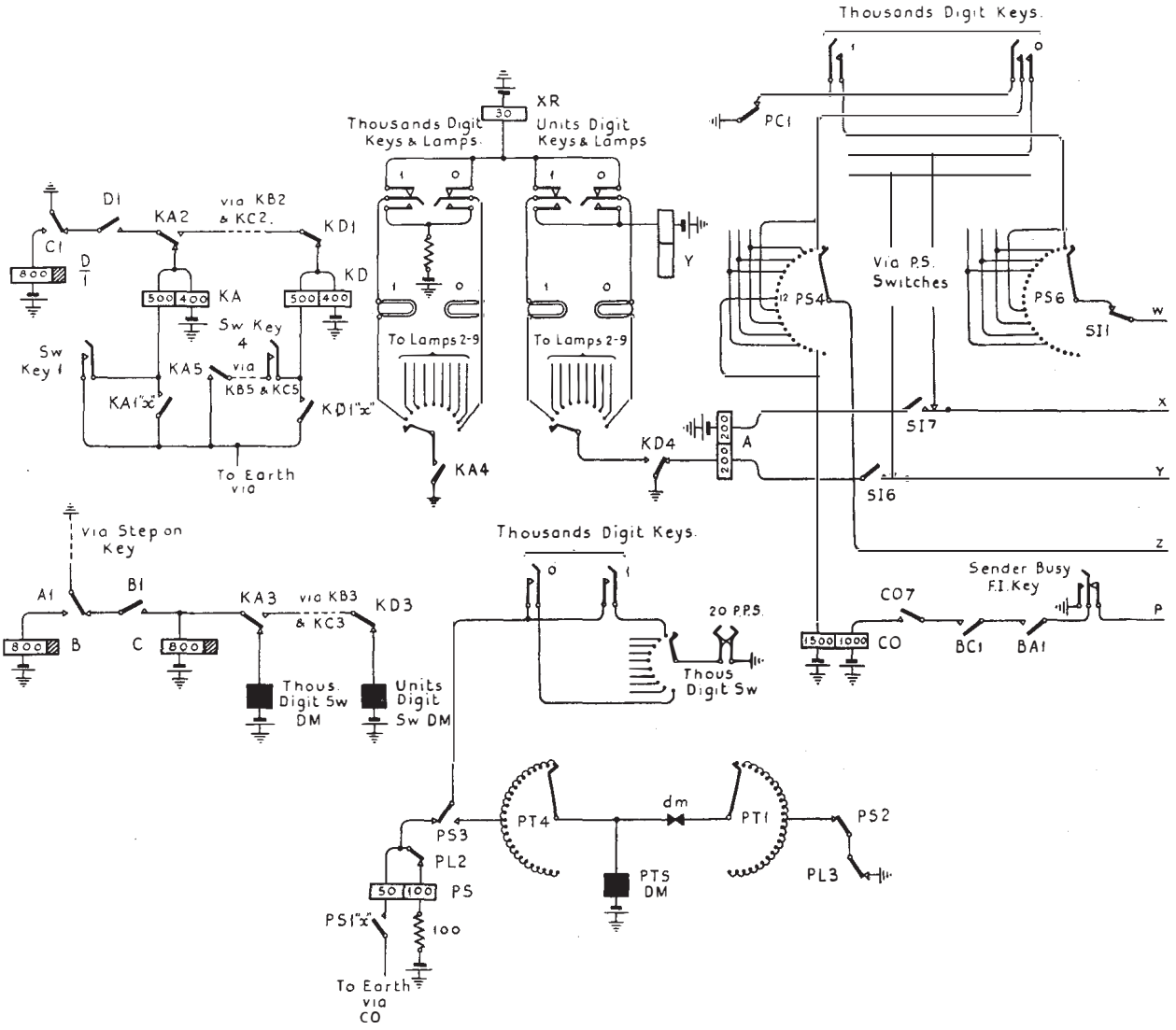


FIG. 6.

this condition, a time pulse is operated in the Sender Finder circuit which applies the start condition to the Sender causing the latter to send digits for routing to the Manual Board. In the routiner, however, since no Sender Finder circuit is employed for the purpose of the test, this condition is simulated and earth is connected to the start lead immediately after the digits have been set up. The receipt of the correct Manual Board translation is then checked.

A typical lay-out of a Sender Routiner is shown in Fig. **7**.

Keysending " B " Position Apparatus Routiner.—The Keysending " B " Position apparatus, as far as this routiner is concerned, comprises all the apparatus, except Senders, which is involved in setting up calls from manual to automatic Exchanges, the items being " Junction Relay Sets," " Outlet Relay Sets " (or " Sender and Junction Finder Relay Sets ") and " Position Relay Sets."

The access equipment consists of two main portions (1) The position access equipment by which access is obtained to position leads, thereby enabling the " B " Operator's functions to be simulated and (2) the junction access equipment, by means of which access is obtained to the required leads on each Junction Relay Set. In most cases the equipment mentioned under (1) is mounted on the routiner rack and that under (2) is mounted in the positions.

The routiner provides for testing the Keysending " B " Position apparatus by selecting the unstaffed positions in cyclic order and then, on each Junction Relay Set associated with that position, simulating the normal conditions set up by " A " and " B " operators respectively. A spare subscriber's number is allocated for routine test purposes in order that a complete " through test " of the Junction Relay Sets may be made.

As position equipment is individual to normal traffic channels, it is necessary to arrange for routine testing by means of the Auto Routiner to be carried out during very slack periods. Testing is therefore carried out between 12.0 midnight and 6.0 a.m.

The routiner functions as follows:—

On operation of the Start Key the Position Distributor is stepped to the 1st position, when

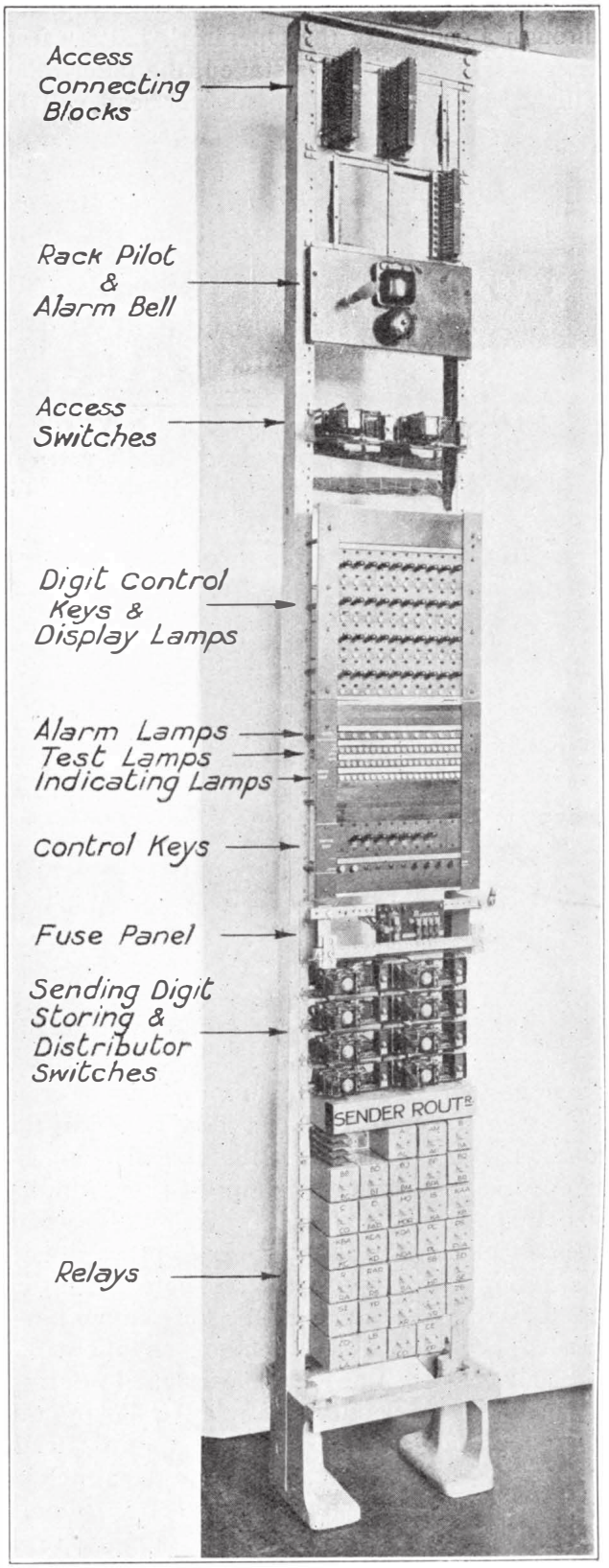


FIG. 7.—SENDER ROUTINER.

a circuit for relay PT (Fig. 8) is completed through a contact of the Operator's battery feed relay. If the position is staffed, the latter relay will be energised and the routiner lead will be

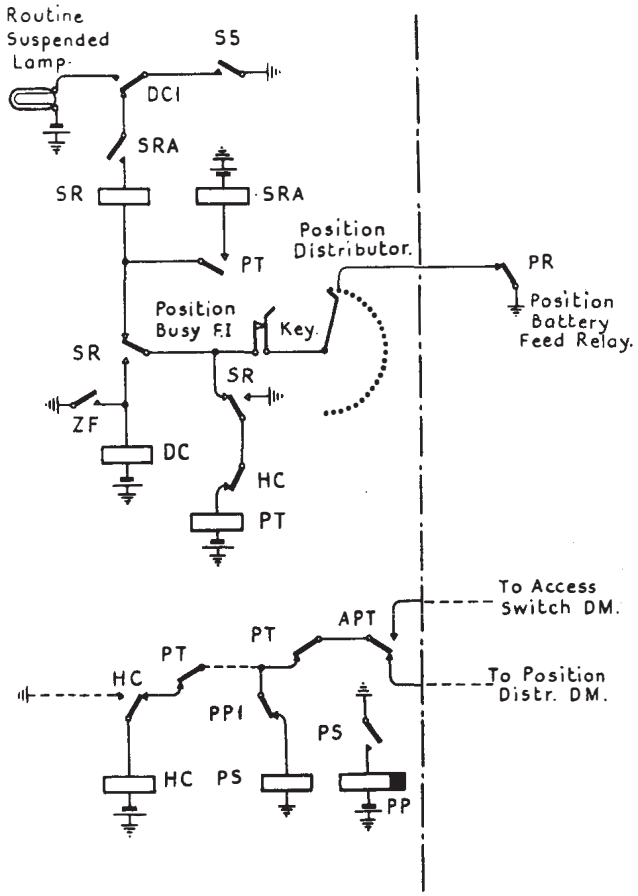


FIG. 8.

disconnected. PT will in this case not operate and, after the release of two slow relays in the routiner, the Position Distributor will again be stepped. This sequence is repeated until an unstaffed position is found. Relay PT now operates and causes the routiner to proceed with the testing of the apparatus associated with this position and also prepares the " Routiner Suspended " feature, which functions as follows :—

Should a position become staffed during routining, the operation of relay PR in the position removes earth from the routiner lead, allowing SR to operate. SR maintains the circuit for PT and starts the " delay set." Should the position be staffed for more than 3 to 6 minutes, relay ZF in the " delay set " operates and energises relay DC. DC lights the " Routine Suspended " lamp and releases relay SR, thereby releasing PT and allowing HC to operate. Relay PT is prevented from re-operation until the Position Distributor has been stepped to the next position. When relay PT released, the homing circuit of the Access Switches was completed. On arrival of the access switches at the home contact relay APT is released and the Position Distributor is stepped to the next unstaffed position.

The routiner having found a free position proceeds to test each Junction Relay Set associated with that position for busy condition, the Access Switch being stepped until the first free relay set is found.

Tests are now applied to the negative, positive and lamp leads of the relay set to prove that they are free from contacts, reversals and disconnections. The routiner then applies an operating condition for the relay set L relay. " Flicker " earth should now be connected to the lamp lead and this condition is checked by the routiner. Thus the supervisory circuit is checked for operation under conditions simulating an " A " Operator seizing the junction before assignment.

The relay set is then released by disconnection of the L relay circuit and then assigned in the normal manner by the routiner. The Sending Switch, which is arranged to transmit the test number (at present 0098), is now started and sets up this number by simulating the depression of the digit keys by a " B " Operator, access being obtained to the position digit leads *via* levels of the Position Distributor. When the number has been set up the supervisory lamp associated with the relay set should glow continuously and this causes a relay to operate and step the Test Switch.

On completion of the set-up of the test number by the routiner, the latter simulates the conditions of the " A " Operator seizing the junction and thus causes " start send " conditions to be transmitted to the Sender.

The Sender now transmits the translated digits which route the call to the test number *via* a final selector. From this point the connection is routed back to the routiner and the final selector applies ringing current, which is received on the routiner ringing relay. This indicates that the call has been routed correctly.

The routiner now trips the ringing in the final

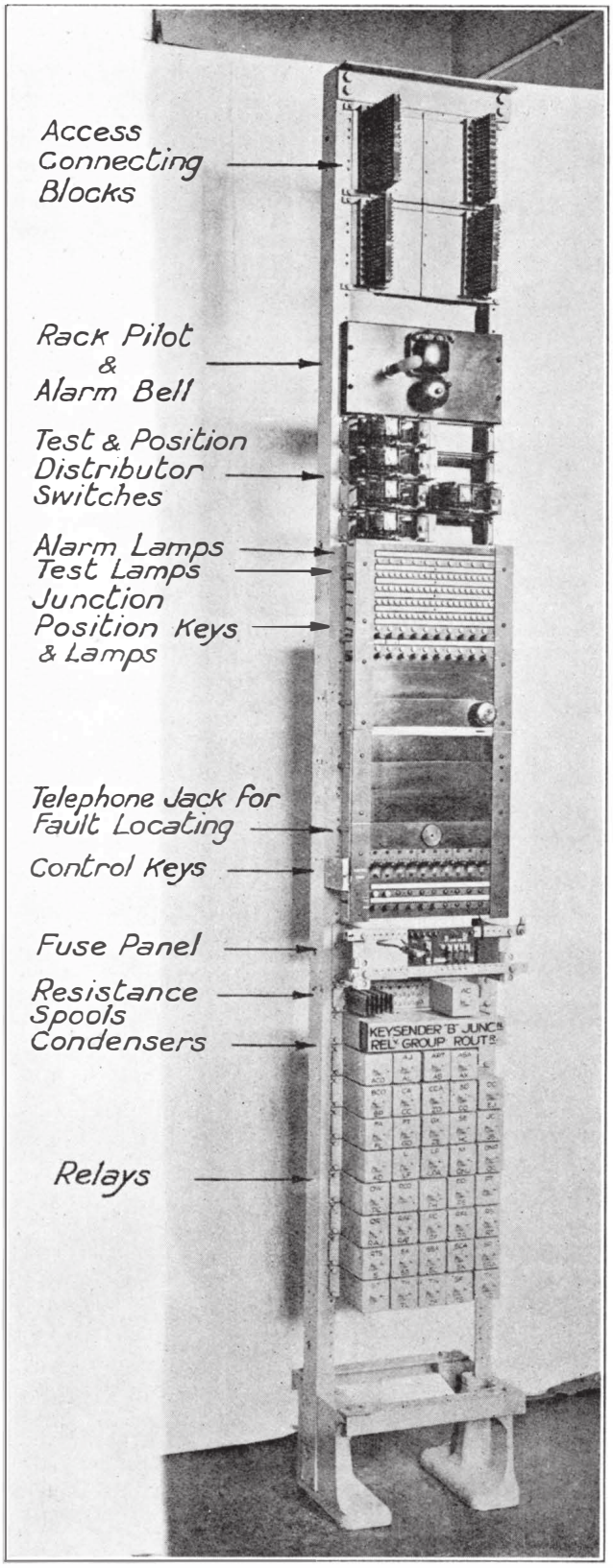


FIG. 9.—KEYSENDING ' B ' POSITION ROUTINER.

selector and checks the receipt of the " Called Subscriber Answering " supervisory condition on the negative line of the Junction Relay Set.

The call is now cleared by the routiner and during release of the Junction Relay Set the period of guard on the private is measured by means of a rotary line switch stepping at 20 p.p.s. as described for other routiners.

The release timing is not included in the later equipments, except where the Junction Relay Sets are connected to outgoing junctions at parent Exchanges in Satellite Areas, as with the advent of the continuous private it becomes unnecessary in the general case.

On completion of the release timing test, the Junction Relay Set is again seized and assigned as previously described. The same test number is now set up in the Sender and a call is again routed to that number; this time, however, the line is busied by the routiner and the correct repetition of busy flash by the relay set is checked.

In addition to the above operation under general routine conditions the routiner is arranged so that it can be used for locating faults. In these circumstances arrangements are made by which the routiner simulates all the " A " Operator's conditions, but assignment and setting up of digits is carried out by a " B " Operator who acts under instructions from the Engineering Staff.

By means of keys the routiner can be connected with a certain position and routine test only the apparatus associated with that position, and by other key operations be connected to a particular Junction Relay Set and continuously test that one relay set.

Fig. **9** shows a " Keysending ' B ' Position " Apparatus Routiner.

This is the last of the series of articles on Auto Routiners, and, in conclusion, it should be mentioned that although the Post Office and all Contractors have contributed greatly to the development of Auto Routiners, most of the original work of design was performed by Messrs. The Automatic Telephone Manufacturing Co., Ltd., in collaboration with the Department.

The Authors desire to express their thanks to Messrs. Siemens for supplying the photographs for publication in illustration of typical routiners.

THE A.T.M. ALL-ELECTRIC TOTALISATOR AT THE ROWLEY MILE COURSE, NEWMARKET.

FOLLOWING the successful demonstration of a 6-horse A.T.M. All-Electric Totalisator before members and officials of the Racecourse Betting Control Board at Thirsk Racecourse, Yorks, on January 8th last, the Automatic Telephone Manufacturing Company Ltd., Strowger Works, Liverpool, proceeded with the equipment of the famous Rowley Mile Course at Newmarket, the first installation of its kind.

The Newmarket Totalisator is designed for a total of 45 runners, the entire equipment, with the exception of certain ticket-issuing machines, located at other parts of the course, being housed in the building which constitutes the main Indicator, Fig. 1.

The Strowger electro-mechanism, which is identical with that comprising Strowger Automatic telephone exchanges all over the world, and daily serving some 6,000,000 telephone subscribers in 32 countries, is made up into detachable component groups, mounted on pressed steel shelves, carried by angle-iron frames as illustrated in Fig. 2.

Each of these component groups of Strowger switches and relays can be lifted from its shelf or replaced within a few seconds, and without disturbing the permanent wiring, a system of interlinked contacts resembling a double comb, one set fixed to the supporting rack, the other attached to the component group, ensuring perfect electrical continuity.

It is this feature which gives to the A.T.M. All-Electric Totalisator its transportable characteristic, and enables the entire equipment for a given race meeting, with a few minor exceptions, to be erected on site just prior to a meeting, and either removed to another racecourse, or stored, immediately following the conclusion of the meeting.

This is a particularly advantageous feature in a country like Great Britain, where the racing season is limited and certain courses have only one or two meetings during the year.

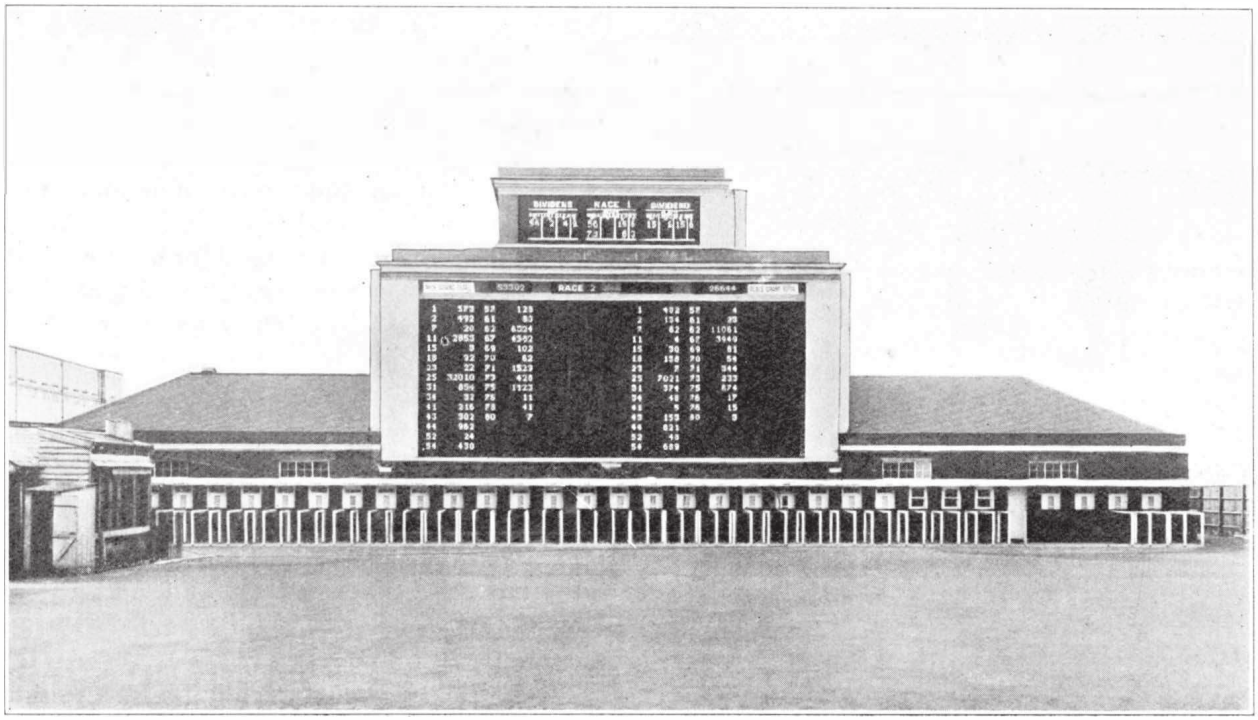


FIG. 1.—TOTALISATOR, NEWMARKET.

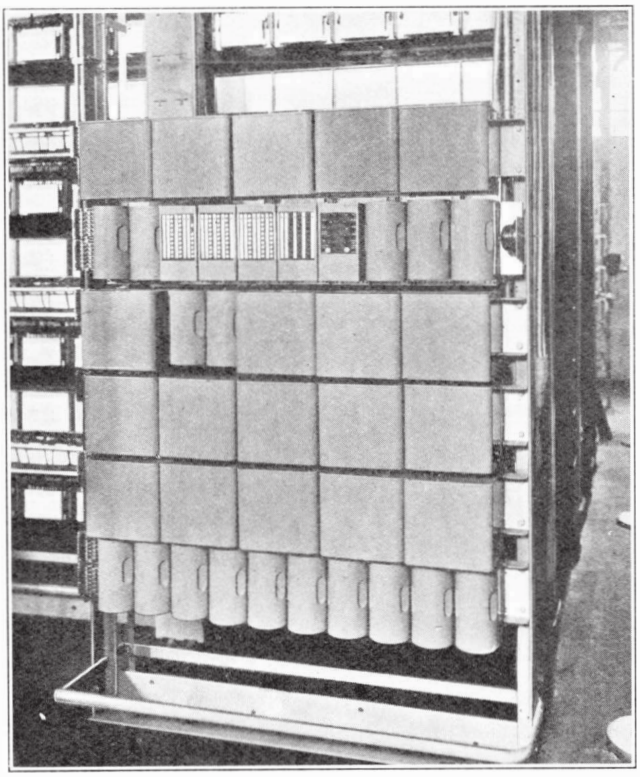


FIG. 2.—RACK MOUNTED APPARATUS.

In countries where racing is carried on continuously and meetings are frequent, the A.T.M. All-Electric Totalisator is equally adaptable to permanent erection, the detachability of the individual component groups remaining an asset on account of the facility it provides for inspection and adjustment.

To avoid delving too deeply into the technicalities of the A.T.M. All-Electric Totalisator, and yet make its operation reasonably clear to the reader, it is perhaps the simplest plan to follow the progress of a bet as staked at Newmarket.

The backer approaches the window of any ticket issuing booth on the course marked with the denomination or value of his stake, 10/- for example.

This is a decided advantage over the previous practice of allocating certain windows to certain horses, which caused congestion and queues due to unforeseen popularity of certain runners and the impracticability of a properly proportioned allocation of windows.

The backer nominates his horse, and the nature of the bet, " win " or " place," whereupon the ticket-issuing clerk depresses the corresponding " horse number " and discriminating keys on one of the two ticket issuing machines and a printed and dated ticket bearing a record of the stake is issued to the backer. The ticket issuing mechanism is so controlled that this does not take place until the bet has been accepted and recorded by the corresponding horse and total adding machines.

There are two ticket-issuing machines to each booth, the corresponding horse numbers dealt with being 1-40 and 41-80 respectively. The reason for the horse numbers being more than is provided for on the main indicator is of course that the numbers of the runners in any given event are not necessarily consecutive, due to withdrawals, scratchings, etc., on the eve of the race.

There are 100 pairs of Ticket-Issuing Machines on the Newmarket Course, 69 of which are accommodated along the sides and one end of the Indicator building, Fig. 1, whilst the remainder are distributed as follows :—

In the Main building, Tattersall's enclosure, eight 2/-; four 10/-; five £1; two £10; one £100; and for chits, four £1; four £10; and three £100.

In the Silver Ring, twenty-eight 2/-; six 10/- and four £1 pairs of machines, making 69 in all, in the main building.

There are two £1 sets in the Trainers' quarters; fourteen in the members' enclosure, comprising six 2/-; three 10/-; four £1; and one £10 pairs; together with four Chit machine pairs, viz., two £1; and two £10.

The total of 100 pairs of Ticket Issuing Machines on the Newmarket Course is made up by eleven in the Paddock Verandah; five 2/-; three 10/-; and three £1.

As will be seen, the machines are of five denominations, two machines to each value, commencing with the unit, (2/-). These values are clearly indicated on the booths and it is only necessary for a backer to select a booth corresponding to the value of his stake, irrespective of the number of his fancied runner.

The Ticket Issuing Machines for Newmarket were supplied by the Bell Punch & Printing Co., Ltd., Uxbridge, and incorporate a number of Strowger relays and a special coding feature which materially reduces the number of wires

between these machines and the main equipment. This portion of the equipment was designed and manufactured by Automatic Telephone Manufacturing Company, Ltd. The Bell Punch Totalisator Ticket Machine is essentially a miniature printing press, embodying in addition all the selectivity, impulse generation, and control necessary for its special purpose. Furthermore the machine is fool-proof, fraud-proof, and immune from deterioration, or the detrimental effects of varying atmospheric changes.

Depression of the keys of these several machines, in accordance with the requests of backers, closes electrical circuits and sets in motion the chain of Strowger electro-mechanism terminating in the registering and indicating devices which keep the public informed of the progress of betting preceding each race.

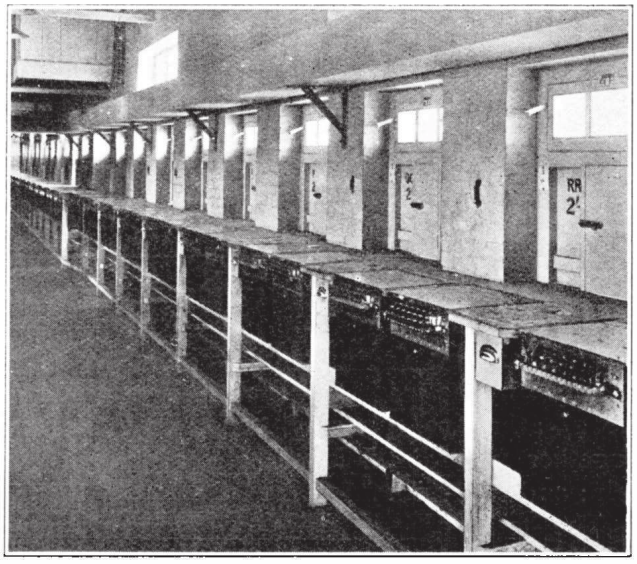


Fig. 3.—Inside front, showing Ticket-issuing Machines.

From the ticket issuing machines, Fig. **3**, which resemble a type-writer or cash register, the electrical circuits (ten wires per machine) pass to the main equipment, *via* a main distributing frame, Fig. **6**, on which the incoming cables to the Totalisator terminate and from which the interior wiring branches out, in orderly sequence, to the various component groups of apparatus.

The first sets of components to receive the electrical impulses initiated by the ticket issuing keys are the " Place Change-over " relay groups, whose function it is to discriminate between " win " and " place " bets and divert them into their respective channels.

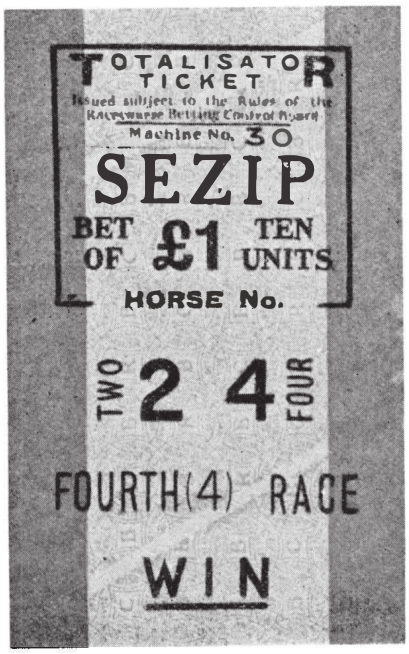


Fig. 4.—A " Win " Ticket.

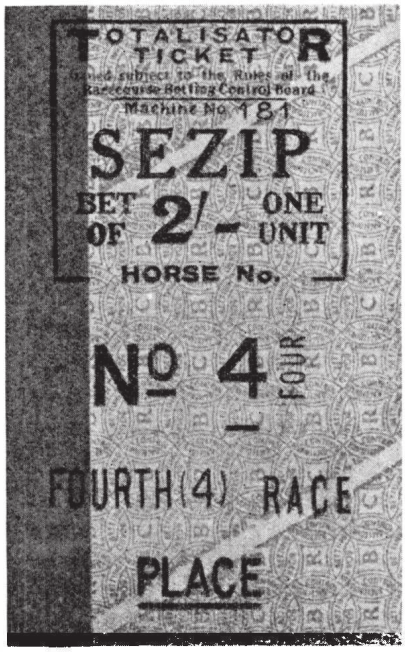


Fig. 5.—A " Place " Ticket.

Next in order come the Decoding Relay groups, Fig. **8**, which transform the key signals into their corresponding betting equivalents, and pass them on to the " Collecting Switches."

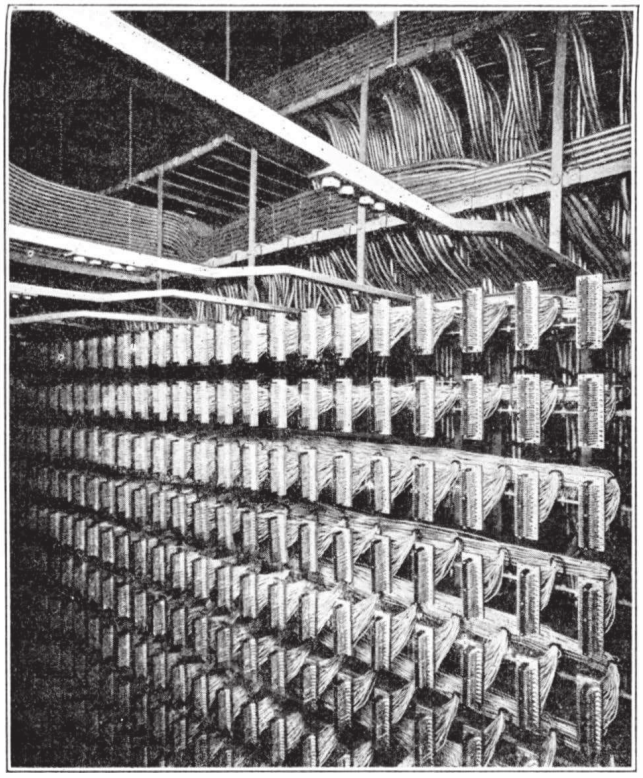


FIG. 6.—M.D.F.

These latter comprise Strowger heavy duty rotary line-switches, their function being to successively collect the bet signals from the various ticket issuing machines. Whilst betting is in progress, these switches are continuously rotating at a speed of about 50 r.p.m., the brushes traversing 2,400 contacts per minute, which provides an ample margin for the prompt acceptance of bets during the busiest pre-race period, when all Ticket Issuing Machines may be in use simultaneously.

The final equipment link in the chain of mechanism associated with each runner is the Horse Adding Machine, a combination of Strowger heavy duty rotary line-switches and relays, which aggregates the bets received from the collecting switches and transmits the resultant totals to the Indicator for visual display.

In addition to the Horse Adding Machines, of which there are two to each runner, adding " win " and " place " bets respectively, there are also two Total-Adding Machines, " win " and " place," which total up all bets and pass them to the " Total " display panels on the Indicator, where the ratio between these grand totals and those of the respective runners gives an indication to the public of the " odds " prevailing at any moment.

During the busiest period immediately prior to the start of a race the various totals change very rapidly, the several adding machines being in continuous operation. Due to the simplicity of the circuits, however, and the absence of any need for electrical synchronisation of the switches, the utmost accuracy is assured.

The whole of the component groups of apparatus so far described, together with the Ticket Issuing Machines, are inter-changeable within their respective classifications, facilitating immediate remedial measures in the improbable event of any temporary derangement, whilst a comprehensive system of supervisory lamp signals gives instantaneous visual indication of a hitch at any point in the system.

As will be seen in the illustration, each group of apparatus has an individual dust-proof metal cover, whilst slip-on covers also protect the wiring, terminals, etc.

Following our imaginary bet in its progress through the chain of mechanism, we have now reached the stage at which it is ready for adding to the corresponding horse and grand totals displayed on the main Indicator.

As will be noted, Fig. 1, the Newmarket Indicator is on the lamp monogram principle, each numeral being delineated by a selected group of lamps in a rectangular lamp-box containing 24

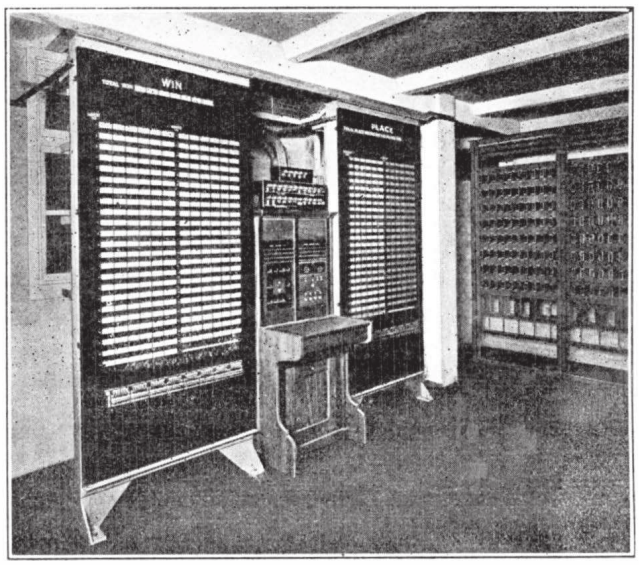


FIG. 7.—CONTROL SWITCHBOARD.

lamps. Each lamp is housed in a light-tight compartment insulated from its neighbours. The lamps are of the Mazda " sign " type, gas-filled, 100 volts, rated at 15 watts, and the effect of these displayed numerals is such that they are clearly visible, in direct sunlight, from a distance of 150 yards and at any angle up to 30 degrees.

There is thus ample notification to the assembled racegoers on the course of the state of the betting at any time.

At the back of each lamp-box is a Strowger relay control group, which selects the various sets of lamps to form the correct numerals according to the signals received from the several adding machines.

Each lamp-box and its associated mechanism is self-contained and interchangeable with any other, on the same principle as the main mechanism groups, and the removal and replacement of a box or boxes during betting does not affect the displayed totals or introduce errors into the automatic calculations in continuous progress.

The complete Indicator, shown in Fig. 1, is duplicated on the opposite side of the building, so as to be visible from both Tattersall's enclosure and the Silver Ring simultaneously.

There are 16 lamp boxes for each runner, two for the horse number and six for the totals, " win " and " place " respectively. The corresponding grand totals call for seven boxes each, or fourteen in all.

Forty boxes make up the Race Dividend display, there being two panels available for possible dead-heats in either " win " or " place " together with " Second " and " Third " horse display panels.

In all there are 1,418 of these lamp-boxes in the Newmarket Indicator, embracing a grand total of 33,798 Mazda lamps. The working voltage of the lamps is 100, and the load, on full display, *i.e.*, with a full complement of 45 runners, and evenly distributed betting, would be of the order of 1,200 amperes.

The Strowger Automatic switching equipment operates at 50 volts and the corresponding load represented by the mechanism in operation would approximate to 300-400 amperes.

The necessary current for operating the Newmarket Totalisator is derived from storage batteries mounted on motor-lorries and kept charged by petrol-engined generating sets, also mounted on lorries for transportability.

With the exception of the Ticket Issuing Machines, the location of which has already been referred to, the whole of the equipment of the A.T.M. All-Electric Totalisator at Newmarket, so far described, is accommodated on the first floor of the Indicator building, immediately behind the Indicator, in what is known as the Machinery Room, and is controlled from the floor below, which constitutes the Control Room.

The most important item of equipment in this room is the Central Control Switchboard from which the whole of the betting, including the issue of tickets at any point on the course and the horses running in each event, can be controlled. Betting can be started, stopped, or modified as necessary, from this central switchboard, and, once the control switches have been set for betting in accordance with the agreed procedure on any given race, the Control Board is locked to prevent accidental operation of the control keys, or unauthorised interference whilst the race is in progress. This facility is one of

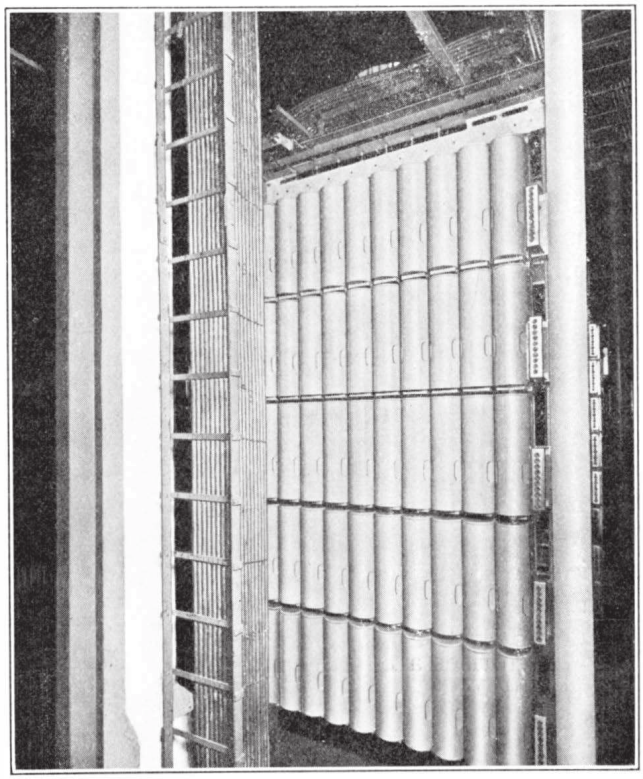


FIG. 8.—APPARATUS RACK AND CABLING. DECODING RELAY GROUPS.

several which effectually safeguard the racegoer against fraud.

The Control Board is equipped with a number of keys and corresponding signal lamps, one key representing each horse and each total adding machine, " win " and " place " respectively. Betting is started by manipulation of the corresponding keys at the control board. Thus, if both " win " and " place " betting are permitted, the total " win " and total " place " keys are operated, followed by the various horse " win " and " place " keys representing the actual runners. If there is no " place " betting these keys are left normal, and it is impossible for the ticket-issuing machines to accept " place " bets. Restoration of the horse and total keys to normal immediately stops all betting, inasmuch as the issue of tickets is controlled from the adding machines, and a horse-adding machine cannot continue in service unless the corresponding total-adding machine is also working. The signal lamp associated with each key glows as long as the key is in the operated position, and enables the controller to see at a glance what portion of the equipment is working and registering bets.

On each side of the Control Switchboard, Fig. **7**, are miniature Indicators, " win " and " place " respectively, which faithfully reproduce the indications on the main indicator and keep the Controller informed of the progress of betting.

Immediately above the Switchboard is a system of supervisory signal lamps of different colours which, by lighting, under distant control, keep the controller advised of the carrying out of miscellaneous instructions issued by him to the various points of the course.

Immediately to the right of the right-hand Miniature Indicator, Fig **7**, are the " Win " and " Place " Plugging-Down Racks, which enable the operators to display non-consecutive horse numbers in regular sequence on the Main Indicator and thus eliminate gaps which would otherwise occur in the case of non-runners.

The remaining equipment in the Control Room comprises a Dividend and Horse Number Display Rack for manual operation at the conclusion of a race; a miniature Dividend Display Indicator, a set of Supervisory and Control Panels and a Power Switchboard. All this is permanent equipment, as distinct from the transportable Strowger mechanism groups, Lamp Boxes, and Ticket Issuing Machines.

Similar permanent equipment in the Machinery Room above includes the Main Distribution Frame, Fig. **6**; three Intermediate Distribution Frames; eight Decoding Group Racks; four Collecting Switch Racks; four Horse Adding Machine Racks; one Horse Adding Supervisory Rack; one Total and Miscellaneous Rack; and a Routiner; together with all the associated permanent cable and wiring, of which there are upwards of 30 miles of all sizes and capacities. The complexity of the cabling will be noted in Figs. **2** and **6**, a large proportion being lead-covered overall.

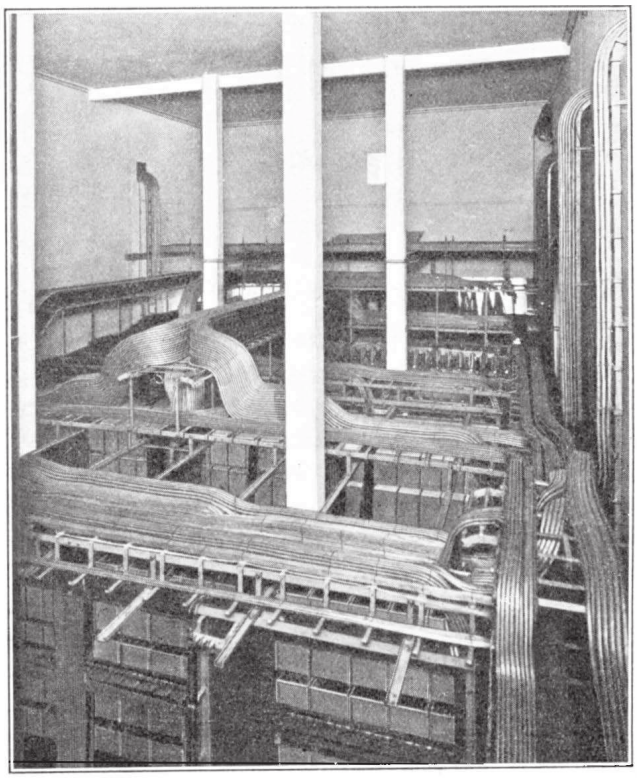


FIG. 9.—CABLING ABOVE RACKS IN MAIN INDICATOR BUILDING

Despite the proved reliability of Strowger Automatic switch mechanism such as is incorporated in the A.T.M. All-Electric Totalisator, it is highly desirable to test or prove out the correct functioning of the equipment following erection and prior to placing it in commission at any meeting.

It is the function of the Routiner, above referred to, to carry out this routine testing auto-

matically and within a minimum time. This most ingenious adaptation of Strowger mechanism to the duties of a maintenance electrician will effectually operate and test the whole of the Newmarket equipment, under actual working conditions, within the short space of 15 minutes, giving instant indication of an abnormal condition at any point.

An application of the Routiner, just prior to the commencement of betting, ensures that everything is in order and relieves the Staff of the tedious routine incidental to testing a large number of electrical circuits by hand.

The schedule of transportable equipment forming the major part of the Newmarket totalisator is as under:—

1418 Indicating Lamp-Boxes.
28 Change-Over Groups.
8 Decoding Supervisory Groups.
400 Decoding Groups.
162 Collecting Switches.
82 Horse Adding Machines.
82 Horse Adding Supervisory Groups.
1 Set of Miscellaneous Supervisory Groups.
200 Ticket Issuing Machines.

The whole of this equipment can be dismounted from its supporting shelves and racks without disturbing a single permanent electrical connection and transported for use elsewhere, or stored against future requirements.

Only the racks, cable, and wiring, and the Control Room equipment remain permanently *in situ*.

The All-Electric Totalisator equipment for Newmarket was designed, manufactured, and installed by Automatic Telephone Manufacturing Company, Ltd., Strowger Works, Liverpool, and supplied to the Racecourse Betting Control Board through the main contractors, the British Thomson Houston Co., Ltd., Rugby. The celerity with which the contract has been completed will be appreciated when it is realised that, following the placing of the order, on November 16th last year, installation of the racks and cabling on site commenced on the 8th of January, and was completed by the end of February, in readiness for the equipment, which was in process of manufacture concurrently.

This was placed in position on the racks and tested out by March 24th, being handed over to the Racecourse Betting Control Board on April 6th for the training of their staff.

A successful Demonstration was given to the Board and officials on the 14th of April, leaving all in readiness in ample time for the Craven Meeting on April 23rd, 24th, and 25th, truly a record achievement.

The advantages of the A.T.M. All-Electric Totalisator over existing mechanical types consist in the absence of inertia of the moving parts; the well-proved reliability of the Strowger automatic telephone exchange mechanisms of which it is comprised; the enhanced visibility of the luminous indicator; the flexibility and transportability of the component groups of apparatus; the compact nature of the equipment and consequent facility for its accommodation as contrasted with large groups of electric motors required for driving the mechanical type of Totalisator; a limited maintenance personnel; and minimum wiring between indicators, control equipment, and ticket issuing machines.

The A.T.M. All-Electric Totalisator can remain in operation up to the actual start of the race, thus securing the whole of the stake money, including the considerable sums deposited during the last few minutes.

The slower, hand-worked totalisators have to be closed down an appreciable time before the "off," in order to have the dividends ready as soon as possible after weighing in.

Precautions against fraud and forgery of tickets are absolute. Tickets are printed only as required by backers, the wastage caused by the use of pre-printed tickets being therefore eliminated. Immediately the "off" has been signalled the mechanism is locked, thus rendering it impossible to issue a ticket after the race has started.

The A.T.M. All-Electric Totalisator is covered by World Patents.

COMMISSION MIXTE INTERNATIONALE.

MEETING AT DOLLIS HILL RESEARCH STATION.

IN 1926 the Comité Consultatif International des Communications Téléphoniques à Grande Distance (C.C.I.) issued certain "Directives," or Guiding Principles, dealing with the protection of international telephone lines against interference by the operation of power circuits. In these Directives the C.C.I. tentatively defined the amount of power circuit interference noise that could be considered as tolerable on an international telephone line. A distinction was drawn between overhead and underground telephone circuits and the definitions are as follows:—

"Interference to telephone working occurs when a power line by electro-static influence develops between the conductors of the telephone circuit a voltage equivalent (as regards the intensity of noise in the telephone receivers) to an alternating voltage greater than 5 mV. at a frequency of 800 periods (5000 radians) per second."

"By reason of the small degree of cross-talk admissible for international telephone lines in cables, the permissible disturbing voltage on the circuits should not exceed the value equivalent (as regards the intensity of noise set up in the telephone receivers) to an alternating potential of 2 mV. at 800 periods per second."

These definitions were not accepted without question and when the Commission Mixte Internationale (C.M.I.) was set up, the subject of tolerable noise and how to measure it was one of the first questions put down for study. It should perhaps be explained that the C.M.I. is an offshoot from the C.C.I. and was set up to carry out actual investigations into problems of joint interest to the communication and power industries. It is composed of representatives from the C.C.I. (Telephones) and C.C.I.T. (Telegraphs), the International Union of Railways, the International Union of Producers and Distributors of Electric Eenergy, the International Union of Tramways, the Institutions of Electrical Engineers of different countries, the Syndical Union of Gas, France, and a number of electrical firms intimately concerned with electrical communications. Problems which are not matters of opinion but which can be settled by actual investigation are referred to a Comite D'Etude, formed from members who are definitely interested in the particular work, with a President Rapporteur in control. The individual members are expected to carry out investigations in their own countries and keep the other members informed of any progress made, and, depending upon the nature of the investigations, they are expected to invite the other members of the C.M.I. to attend the place where the tests are being made if the circumstances are favourable.

The question of tolerable power circuit noise and its measurement is being dealt with by Committee No. 6, with Mr. S. C. Bartholomew, of the British Post Office, as President Rapporteur. This Committee met at the British Post Office Research Station, Dollis Hill, London, from Monday, 17th March, 1930, to Wednesday, 19th March, 1930, to collaborate in comparative tests of different methods of noise measurement and to discuss the results and the question generally. In conformity with the rule previously mentioned, other members of the C.M.I. were invited to attend also, and those present included representatives from several Continental Telephone Administrations, international power interests, large electrical manufacturing companies, the Institution of Electrical Engineers and the Central Electricity Board.

There are two methods of noise measurement that have been used up to the present, one German (Geräuschspannungsmesser), the other American (Noise Measuring Set). The former is practically that laid down in the Directives, which, in effect, is a comparison between the noise it is desired to measure when heard on a special telephone receiver and that produced on the same receiver by a current of a single frequency of 800 per second passing through a certain network, the balance being expressed in millivolts measured across a potentiometer, which is adjusted to give what is considered a balance in volume. The American system is somewhat similar, except that a standard buzzer is used

instead of the 800 frequency generator, the test line is terminated with approximately its own impedance and the results are given in noise units which are millionths of the current output of the buzzer. Fig. **1** (figs. 2 & 3) illustrates in diagram-

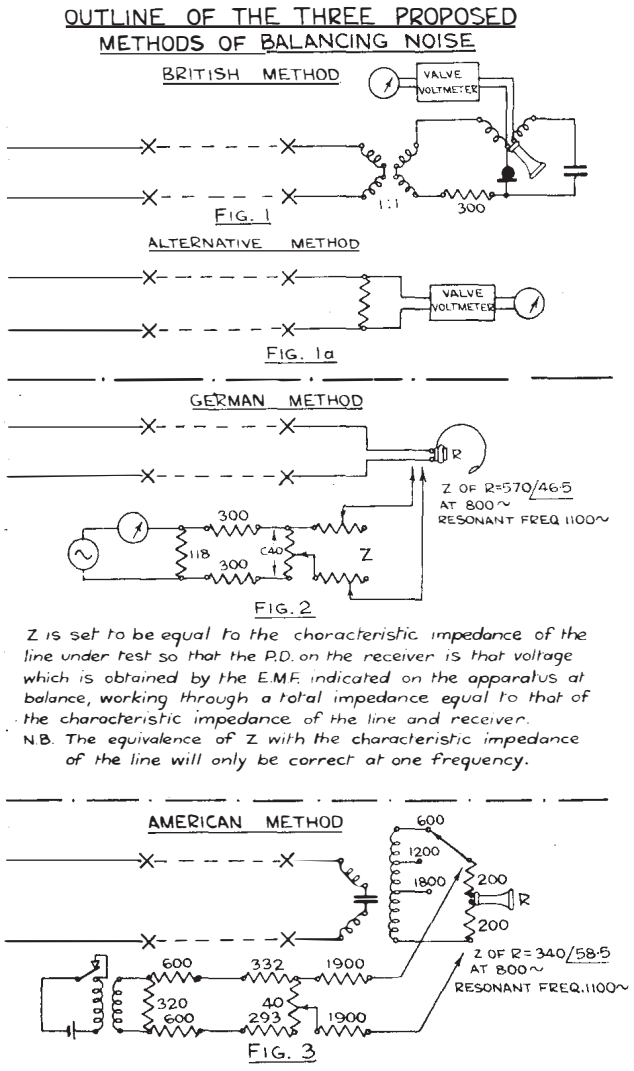

OUTLINE OF THE THREE PROPOSED METHODS OF BALANCING NOISE
BRITISH METHOD
VALVE VOLTMETER
1:1
300
FIG. 1
ALTERNATIVE METHOD
VALVE VOLTMETER
FIG. 1a
GERMAN METHOD
R
Z OF R=570/46·5 AT 800~ RESONANT FREQ 1100~
300
118
300
C40
Z
FIG. 2
Z is set to be equal to the characteristic impedance of the line under test so that the P.D. on the receiver is that voltage which is obtained by the E.M.F. indicated on the apparatus at balance, working through a total impedance equal to that of the characteristic impedance of the line and receiver.
N.B. The equivalence of Z with the characteristic impedance of the line will only be correct at one frequency.
AMERICAN METHOD
600
1200
1800
200
R
200
600
332
1900
320
600
40
293
1900
Z OF R=340/58·5 AT 800~ RESONANT FREQ.1100~
FIG. 3
The line is terminated approximately with its characteristic impedance (see note re German test) and at aural balance the result is given in millionths of the current from the buzzer.

Fig. 1.

matic form these two sets of apparatus. Both these methods have certain admitted drawbacks, although good results are claimed for both types of apparatus when observers have had experience. The criticisms of the German apparatus are that the actual measurement is not easy to make and is heavily biassed by the personal opinion and aural peculiarities of the observer, and the results are based upon loudness of noise produced by the disturbance and have no direct relationship with the effect upon articulation. This last is important, as it has been shown that the articulation loss varies with frequency; for example, a given volume of 800 frequency disturbance produces much less effect upon articulation than the same volume of 1100 frequency, or telegraph type disturbance. Another criticism is that the tests are made under arbitrary conditions as regards line terminations, and the results depend largely upon the condition and characteristic of the receiver used. Unless the receiver is non-resonant, its characteristics may be such as to give misleading results if its natural frequency is the same as the power circuit interference note, or contains a similar frequency harmonic. Finally, reasonably silent conditions are required. Some of the above disadvantages hold good in the case of the American apparatus, although the conditions as regards line terminations are better and a composite note is considered preferable for comparative purposes by some observers. There is, however, an additional drawback in that the results depend very largely upon the condition of the buzzer and the cells.

In view of these difficulties, particularly the one of personal equation in judging noise, a suggestion had been put forward by the British Administration that a better way would be to measure the potential difference produced by the power interference, either at the receiver terminals or at the terminals of the international line, and correlate the voltage measured in that way with loss of articulation according to the frequency or frequencies of the interfering current. Curves illustrating the connection between loss of articulation, disturbing frequency and voltage are given in Fig. **2**. To obtain these, the procedure consisted in terminating an artificial test line with a standard Post Office cord circuit and subscriber's instrument, on the receiver of which the listening was done and voltage measurements made. Numerous receivers and observers were used. The articulation tests were made under comfortable conditions by a considerable number of observers for various disturbing voltages.

In practical use the procedure, it was suggested, would be to measure the disturbing voltage on the receiver terminals or at the end of the

international line, and then on the appropriate curve to read the articulation loss or, of course, from the curves a definite figure for the allowable voltage of any kind of disturbance could be settled and worked to.

The valve voltmeter used has a lower cut-off of about 200 and an upper cut-off of about 3,500. It should be clearly understood that the relationship between millivolts disturbance and reduction in articulation is not in any way arbitrary. The relationship as given in the curves are the one and does not depend upon the aural impression of an individual. The reading can be taken quickly and an average effect based upon a large number of observers using a large number of receivers is obtained from the Laboratory results already made, once and for all. As is to be expected, opinions as to equality of volume of two sounds of different character vary widely and render any balances by ear of these sounds very unreliable unless a large number of observers are employed.

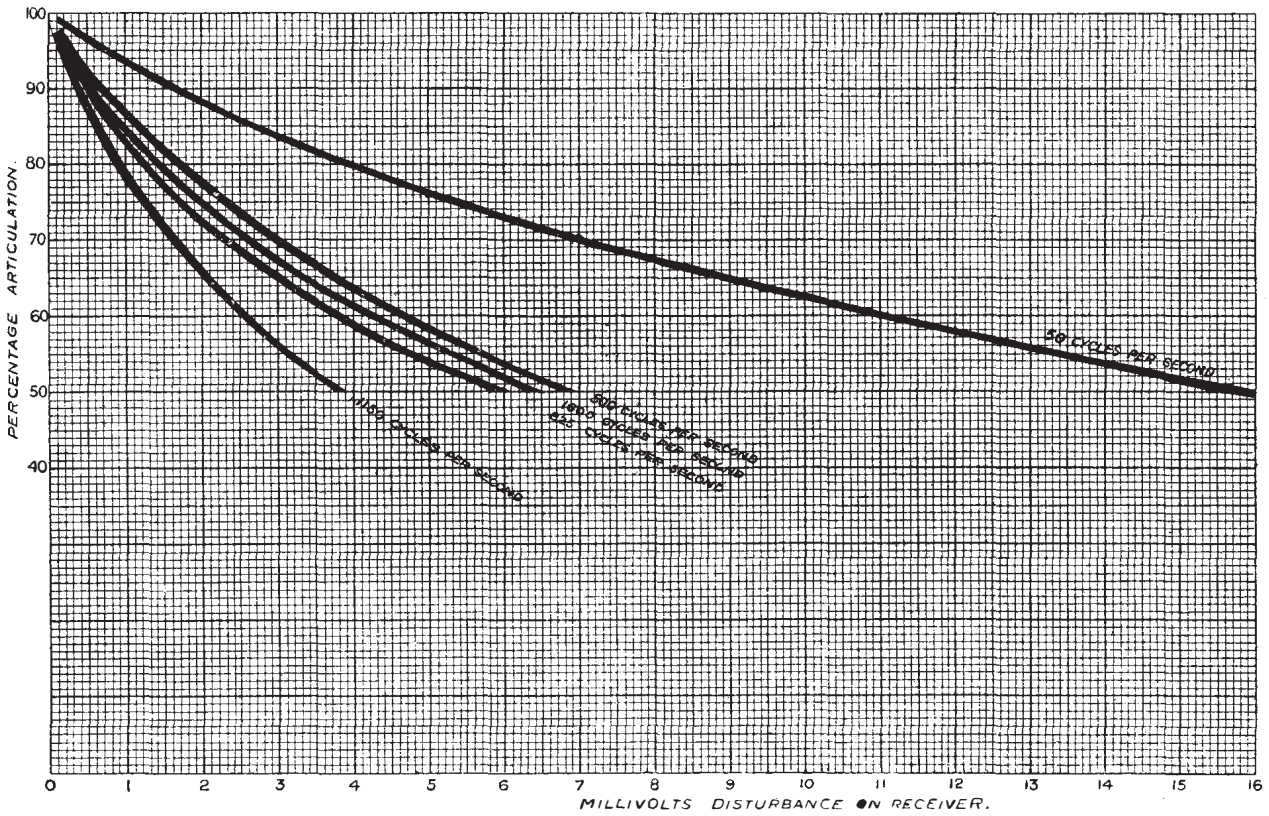


FIG. 2.—CURVES SHOWING RELATIONSHIP BETWEEN LOSS OF ARTICULATION, FREQUENCY OF DISTURBANCE AND VOLTAGE OF DISTURBANCE ON RECEIVER.

results of actual measurements and within the limits of experimental error may be accepted. These tests were made by ten observers with various line conditions, using six receivers and five transmitters. It is possible that with different languages and with the various receivers used in other countries some modification of the figures may be found to be desirable, but in no sense is the relationship arbitrary.

The great advantage of this method lies in the fact that the measurement is purely a physical

A criticism has been made that as the induction occurs on the line the measurement should be made there, but this objection does not seem to be very important as it is a simple matter to convert the potential difference measured on the receiver terminals into corresponding potential difference, either at the end of the Trunk line or at any point on the line if the conditions are known.

The first proposal was to measure the potential difference by means of a valve voltmeter and

from that deduce the loss in articulation according to the frequency of the power circuit note as shown on the curves. This would have meant a classification of the interfering note into different categories, and the evolving of some ready means of analysing approximately. This difficulty was got over, however, by devising a filter circuit to be associated with the valve voltmeter, the filter being so arranged that the readings would be weighted in accordance with the effects of the various frequencies in loss of articulation. If a reference is made to the curve it will be seen that with similar conditions the loss is greatest with a frequency of about 1100 per second, and that the loss falls off with frequencies lower and higher than that figure. H. S. Osborne, of the American Telephone and Telegraph Company, in a paper before the A.I.E.E. gave in 1919 results of investigations carried out by the A.T. and T. Co. which bear out this point, but probably owing to a different method being employed in assessing the loss, the Osborne curves do not exactly agree with those obtained at Dollis Hill. Osborne's work was concerned with ascertaining by means of a current measurement the comparative effects of different power generators in producing interference with telephones, and he designed a filter which had the effect of weighting the readings in accordance with the frequencies of the harmonics in the current and voltage waves of the power system. It will be seen, therefore, that the idea of using a measuring set having a net-work which has characteristics the inverse of the characteristic interference frequency curve is not new, except that it is applied to the telephone line instead of to electrical power machinery.

The above briefly indicates the position of affairs which the members of the C.M.I. present at Dollis Hill had to discuss and deal with. The different types of apparatus were installed and those present had an opportunity of making measurements with the German and American apparatus.

Comparative measurements were made by all members of the Commission by the three methods, four different types of disturbance being examined. The results by different observers showed wide discrepancies by both German and American procedure. It became evident during the course of the tests and discussion that there was general agreement, that an objective test as proposed was to be preferred to the subjective method of measuring by ear, and to that extent the problem was considerably simplified; the outstanding points then being (*a*) as to whether the British curves associating the voltage readings with loss of articulation could be taken as applying to all countries, and (*b*) the percentage loss of articulation that could be agreed as tolerable on an international line. As regards (*a*) it was suggested that the different languages and the different receivers might affect the shape of the curve, but the opinion was expressed that probably when the matter is tested out a curve will be found suitable for all countries, and from which a measuring instrument for universal use could be manufactured. As regards (*b*) Mr. Bartholomew pointed out that in this matter the last word must be with the Transmission Section of the C.C.I. (3rd C.R.). He contended that a mixed body of power and telephone engineers not directly concerned with telephone transmission problems was not in a position to come to a decision on such a question. It must be dealt with by experts. The committee in question (the 3rd C.R.) had tentatively suggested a maximum articulation loss of 5%, but further study was necessary before a decision could be expected, as the fixing of the figure must receive very serious consideration, taking into account the fact that it is now possible for 90% of the telephone subscribers in the world to be placed in communication with one another, and the effect on all the links in the chain must be borne in mind.

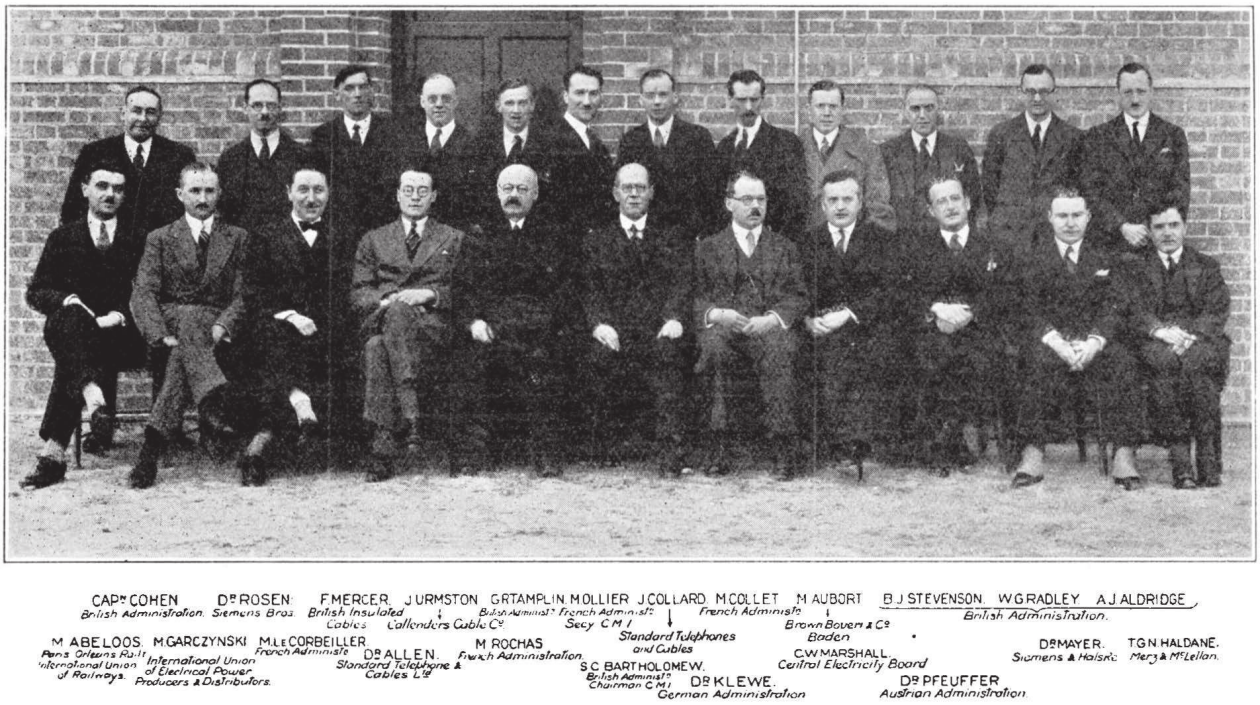
The work at Dollis Hill resulted in great progress being made by clarifying the problem, and indicated the steps necessary to arrive at an agreed solution.

A group photograph of the representatives appears on page 137. It does not show all those attending, however, as Dr. King, of the American Telephone and Telegraph Co., Mr. Grinsted, (Siemens), Mr. Dunsheath (Henleys), Mr. Marris (G.E.C.), Mr. Werren (G.E.C.), and Col. Carter were absent on this occasion. For the convenience of the visitors who stayed in London an auto-bus was used for conveyance each day between the Institution of Electrical Engineers and Dollis Hill. The new building at Dollis Hill was used for the first time

and proved in every way an admirable meeting place for such a gathering. The handsome Lecture Hall provided not only facilities for adequately carrying on the discussion, but enabled moving pictures to be shown illustrating work in connection with automatic apparatus and the jointing of underground cables. The visitors were supplied each day with luncheon and tea in the building, the service being very satisfactory. On the Wednesday the Standard Telephones and Cables Co. invited the Commission to dinner at the Savoy Hotel. This was a most enjoyable affair. The dinner was very well chosen, the special orchestra was very pleasant, there were no speeches and the cabaret show was decidedly good.

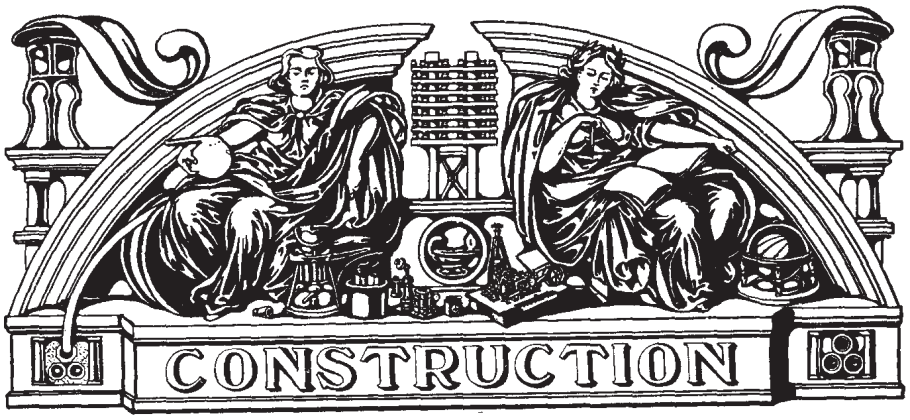
Complete satisfaction was expressed by the members of the Commission for the arrangements for the meetings and for their material welfare. Among letters of appreciation received, one was written to Mr. Bartholomew in English very feelingly, the final sentence reading "Thank you for all your kissness." The slight slip was no doubt due to the articulation loss being greater than 5%, but in order that there shall be no misunderstanding it is emphasised that no ladies were present!

S.C.B.


CAPt COHEN British Administration.
Dr ROSEN Siemens Bros.
F MERCER British Insulated Cables
J URMSTON Callenders Cable Co
G R TAMPLIN British Administn
M OLLIER French Administn
Secy C M I
J COLLARD
M COLLET French Administn
M AUBORT
Brown Boveri & Co
B J STEVENSON
W G RADLEY
A J ALDRIDGE
British Administration.
M ABELOOS International Union of Railways.
M GARCZYNSKI International Union of Electrical Power Producers & Distributors.
M Le CORBEILLER French Administn
Dr ALLEN Standard Telephone & Cables Ltd
M ROCHAS French Administration.
Standard Telephones and Cables
C W MARSHALL Central Electricity Board
S C BARTHOLOMEW British Administn Chairman C M I
Dr K LEWE German Administration
Dr PFEUFFER Austrian Administration.
Dr MAYER Siemens & Halske
T G N HALDANE Merz & McLellan.

C.M.I. CONFERENCE MARCH 1930.

FIG. 3.



THE THEORY OF CORROSION.

C. E. Richards, A.I.C.

THE wastage due to metallic corrosion is nowadays assuming huge proportions. The annual loss from this cause has been estimated by Sir R. A. Hadfield to be about £500,000,000. This is an enormous amount, and it is only natural that strenuous efforts are being made at the present time to minimise the effects of this influence. Hitherto, most of the methods suggested for reducing corrosion have been somewhat empirical in nature, as investigators in this field were without a guiding principle. Early workers connected corrosion with the action of acids, notable carbonic acid, others suggested hydrogen peroxide, which is certainly formed when some metals corrode. The action of colloidal hydroxides has also been extensively studied.

Although the connection between the corrosion of metals and electrical phenomena was observed over one hundred years ago, and in fact Davy suggested an electrochemical method for the prevention of corrosion on the copper bottoms of the ships of those days, it was not until very recent years that an acceptable theory was evolved. This new electrochemical theory at first met with severe opposition, but is now almost universally accepted as giving the most reasonable explanation of the observed facts.

The following matter is an attempt to cover briefly the modern electrochemical theory of metallic corrosion in its most usual form.

Corrosive attack can conveniently be divided into two main classes—

(*a*) Corrosion which is accompanied by a visible evolution of gas and

(*b*) Corrosion unaccompanied by any visible evolution of gas.

It is with type (*b*) that we are here mainly concerned, and it has been descriptively called "differential aeration" attack, and "oxygen diffusion" corrosion, since the condition which is generally responsible is a difference in oxygen concentration at various parts of the metallic surface.

Experimental evidence points to the view that supposing it were possible to immerse an absolutely homogeneous metal, say lead, zinc or iron in a perfectly homogeneous aqueous solution, and maintain the solution homogeneous, no appreciable corrosion would occur, but since these conditions cannot be attained in practice, other methods of minimising corrosion must be sought.

The main feature to bear in mind is that any system in which there is heterogeneity in any phase is inherently liable to cause corrosion of the metal concerned, it does not matter whether this variation is in composition of the metal, concentration of the solution, temperature of the solution, etc., any difference from place to place is liable to set up corrosion. In actual practice the effect of electrolyte concentration is usually

small, but variations in oxygen concentration and heterogeneity of the metal surface have considerable effects.

Corrosive attack is always accompanied by variations in electrical potential over the metal surface, some parts becoming anodic and others cathodic whilst, in the normal manner, metal goes into solution at the anodic areas and tends to be deposited at the cathodes.

The fact that potential differences can occur at the junction of two electrolytes similar in composition and differing only in concentration has been proved by the study of cells, which are symmetrical except for the electrolyte. For instance, in a cell with an electrolytic system consisting of two halves, each of mercury in a saturated solution of mercurous chloride in 10% potassium chloride, written symbolically thus :—

$$Hg \;.\; Hg_2Cl_2 : K\,Cl_{10\%} :: K\,Cl_{10\%} : Hg_2Cl_2 : Hg,$$

The whole system being symmetrical, no P.D. can be expected between the two mercury electrodes; if, however, one half of the cell is replaced by another mercury half cell which is constructed with 1% potassium chloride,

$$Hg : Hg_2Cl_2 : K\,Cl_{10\%} :: K\,Cl_{1\%} : Hg_2Cl_2 : Hg,$$

a P.D. can be detected between the two mercury electrodes. Taking the investigation a stage further, Helmholtz studied the cell.

$$Zn : ZnCl_{2(1)} : Hg_2Cl_2 : Hg :: Hg : Hg_2Cl_2 : ZnCl_2 : ZnCl_{2(2)} : Zn,$$

and using concentration of (1) 1 part $ZnCl_2$ to 0.8 parts water and (2) 1 part $ZnCl_2$ to 9.1992 parts water he found that the system had an E.M.F. equal to 0.1154 of that of the Daniell cell used as a standard.

The above results cannot be applied directly to ordinary corrosion cases because the systems considered are theoretically reversible, whilst in corrosion cases this is not necessarily so. They serve to shew, however, that it is possible for differences in electrolyte concentration to cause varying potentials at the metal surface and thus commence corrosive attack.

Considering now the effect of a metal surface of varying composition it is easy to see that even in a homogeneous electrolyte, if there are portions of the metal plate which have different contact potentials to the liquid, local cells will be formed, *e.g.*, in the case of a flake of graphitic carbon embedded in the surface of a piece of iron, the graphite will form the positive pole of the cell, *i.e.*, current will flow from the iron through the solution to the graphite, and as usual, metal will go into solution; the current, taking the shortest path through the solution will leave the metal close to the graphite so there will be formed a corroded ring around it which may start a pit.

In the case where the impurity is in the form of a more electro positive element than the body of the metal, current will flow from the impurity through the solution to the main body, the impurity will be corroded away leaving a hole, again starting a pit.

Each method of corrosion so far described would, however, in practical cases speedily cease were it not for the presence of dissolved oxygen in the corroding medium. We do not, for example, generally deal with concentration cells of the type :

$$Zn : ZnCl_2 : \ldots\ldots : ZnCl_2 : Zn$$

or $$Hg : Hg_2Cl_2 : \ldots\ldots : Hg_2Cl_2 : Hg$$

where the electrodes are in contact with solutions containing abundance of their ions, so that when current flows from the liquid to the electrode, metal is deposited without seriously affecting the concentration of metallic ions in the liquid, but with systems which approximate to

$$Zn : NaCl_{(1)} :: NaCl_{(2)} : Zn$$

where the concentration of metallic ions in the liquid is almost nil. In this connection it is important to remember that when sodium chloride (which may be regarded as typical of any salt) is dissolved in water it does not remain in solution as molecular sodium chloride, but tends to split up into ions of sodium and ions of chlorine each of which carries a definite electric charge, the change being represented thus :—

$$NaCl \underset{aq}{\rightleftharpoons} Na^+ + Cl^-$$

Further, the water itself splits up into ions

$$H_2O \rightleftharpoons H^+ + OH^-,$$

so that in a simple solution of sodium chloride in water there are effectively six constituents in equilibrium with one another.

Reverting now to the case of the simple concentration cell

$$Zn : NaCl_{(1)} : : NaCl_{(2)} : Zn$$

When current is taken from this cell, one zinc pole being anodic tends to go into solution, but at the cathode there is a tendency to deposit metal. The only cations present in quantity in the solution are sodium and hydrogen, but sodium is a very active metal and if deposited on the cathode it would immediately react with the surrounding water giving hydrogen, which would replace it at the surface of the cathode; alternatively hydrogen ions might be discharged at the cathode, the final results being the same in either case. This discharge of hydrogen ions continues until the electrical charges liberated by them have raised the potential of the cathode to such an extent that no more can be discharged, *i.e.*, the potential difference between anode and cathode is equal and opposite to that of the electrolytes surrounding them, so that no current can flow in the circuit. The system is then "hydrogen polarised" like any polarised primary cell. No further current can flow and therefore no more corrosion can occur until the system is depolarised. This is done by the dissolved oxygen in the water and can of course only take place slowly. The rate of solution—or corrosion—of the anode is mainly dependent upon the rate of depolarisation of the cathode. A similar mechanism of reaction applies to the other case mentioned of "local cells" on the surface of a metal plate.

This brings us to a consideration of the role of oxygen in corrosion generally. In all ordinary cases it behaves as a depolarising agent. It is not necessary to assume any variation in composition of either electrolyte or metal at the commencement of the reaction, although these factors undoubtedly assist in establishing a rapidly corroding system. When a metal such as zinc, iron, lead, etc., is immersed in a homogeneous aqueous solution, it possesses a certain tendency (known as the solution pressure) to pass into solution, *i.e.*, to enter the ionic state. (The exact mechanism of the reactions at the surface of a metal plate immersed in a solution are at the moment a matter for speculation, but the following elementary theory gives a broad outline of the subject). It therefore throws off metallic ions into the layer of liquid next to the metal. These ions carrying positive charges leave the parent metal in a cathodic state and between the positively charged liquid and the negatively charged metal a strong electrostatic field exists, and we have an equilibrium achieved in which all the ions present in solution and also the cathodic metal are concerned. In the absence of dissolved oxygen or other depolarising agents the action then ceases, when an entirely negligible amount of metal has entered solution. Normally, however, the dissolved oxygen is free to combine with the cations near the cathode, giving water and metallic hydroxides. The effect of this is twofold; firstly, it reduces the P.D. between metal and liquid, thus allowing more metal to enter solution and, secondly, it depletes the solution of its available oxygen.

This supply can only be replenished by diffusion from (*a*) other parts of the liquid and (*b*) the surface of the liquid exposed to the air. The solubility of oxygen in water being small, the supply (*a*) is soon exhausted and further quantities must be obtained from the surface. This results in a variation of oxygen concentration throughout the liquid and therefore over the surface of the immersed metal. At the places where the oxygen concentration is greatest, *i.e.*, near the surface, the polarising hydrogen is removed most rapidly, and since hydrogen carries a positive charge these areas become cathodic, and the areas of least oxygen concentration anodic, so that a way is opened for the current to flow and, as usual at the anodic areas, metal goes into solution. This action can continue as long as there is a supply of oxygen from the surface.

The above example of a perfectly homogeneous metal in a uniform electrolyte is of course theoretical, but the action of oxygen is the same whether corrosion is started by lack of uniformity in the metal or the solution, and the main point which concerns us is that the metal goes into solution at the parts of the system to which oxygen has the least access. This is very important when the pitting of metal surfaces is under consideration. The original cause of a pit may be one of several, a scratch, an enclosed foreign body, such as a slag enclosure, segregation of some constituent of an alloy, etc. Once the pit is started, the bottom of the cavity being shielded from access of oxygen tends to become anodic whilst the mouth of the pit is cathodic. Metal goes into solution in the pit whilst at the

cathodic area alkaline hydroxide is formed. These two materials diffuse into one another and the usual result is the formation of a gelatinous mass of metallic hydroxide which clogs the mouth of the pit and still further restricts the supply of oxygen to the liquid within. Hence pitting, which is one of the most dangerous of all forms of corrosion, once started tends to become more and more vicious as time proceeds.

The above matter is not the whole story of corrosion; far from it. From the theory as described it could justly be argued that all metals should corrode. Yet we have around us to-day many examples of metallic objects which do not appear even to tarnish after years of service. Stainless steel is a familiar example. In all ordinary circumstances this alloy is uncorroded; it can remain for prolonged periods in contact with liquids of varying concentrations and oxygen content and remain bright. The explanation of this remarkable behaviour is that the metal does in fact corrode, but when it corrodes—or tarnishes—instead of giving a loose porous corrosion product such as generally forms, it gives a compact film which adheres tightly to the metal and effectually prevents the further access of corrosive materials to the surface. The surface is in what is known as a passive condition. Certain chemical combinations have distinct powers of destroying these films and in contact with solutions of this type even stainless steel has a tendency to corrode, *e.g.*, freshly cut surfaces are quite liable to be attacked by salt water (Evans: " The Corrosion of Metals ").

A case which is perhaps of more interest to telephone and telegraph engineers is that of lead and some of its alloys. Lead is a metal which is quite readily corroded, and in the laboratory rapid attack can be made by such reagents as distilled water, lime water and ammonium nitrate. The attack by distilled water on a freshly cut lead surface is so rapid that clouds of lead hydroxide can be seen to form in a matter of seconds. Yet lead and its alloys are almost universally used for such purposes as water pipes and cable sheaths, generally with entire satisfaction. Fortunately for chemical and electrical engineers certain compounds which form protective coatings on lead are very widely distributed. Very few natural waters are found which do not contain these " inhibitors," and even where they do not occur naturally in sufficient quantities it is an easy matter to add the necessary amounts. Calcium bicarbonate is present in the majority of waters and is one of these film-forming chemicals. Sulphates also occur frequently and also help to protect lead. It has recently been observed that silicates are very effective in preventing lead corrosion and in several cases the addition of silicate to a corrosive water has converted it to a harmless one.

In conclusion, it may be said that although corrosion may at first sight appear to be an entirely haphazard occurrence which cannot be foreseen, this is really not so. Corrosive attack follows certain well defined lines, and as more and more work is done on the subject so do the unknown factors concerned become fewer in number, and the chances of avoiding damage from this cause increase.

CABLE INSTRUCTIONAL COURSES HELD AT DOLLIS HILL.

W. T. Palmer, B.Sc.(Eng.), Wh. Ex., A.M.I.E.E., and G. W. Hodge, A.M.I.E.E.

For the first three months of this year a cable instructional course was held in the Research Section of the Engineer-in-Chief's Office, at which 46 officers of the Department attended. The syllabus for this particular course followed closely the general lines given in 1927-28, details of which are described in the Journal for April, 1928, and was divided as follows:—

1. Mathematical Introduction and Elementary A.C. Theory—daily lectures for two weeks.
2. Cable Balancing and Acceptance Tests—Lectures and Practical Work for five weeks.
3. Fault Localisation and Precision Testing—Lectures and Practical Work for five weeks.

in the second part, instruction was given regarding the application of systematic jointing schemes and the use of the 15-Position Testing Switch; and in the third part the application of alternating current for reliable fault localisation results was discussed. Also during the course, by the courtesy of the Standard Telephones and Cables Ltd., a visit was paid by the students to the North Woolwich Works of that firm and supplementary information in connection with modern telephone cables was obtained.

As in previous cases, the 46 members of the cable class were drawn from the ranks of the Department's Inspectors, Repeater Officers and Skilled Workmen, and one or more officers attended from almost all the Engineering Districts. The happy associations which are formed

Cable Instruction Class at Dollis Hill, 1930.

Some alterations and additions were made to bring the above course into line with the latest practice. In the first part, the Network Theorem was shown to be of more than academic interest; during such a three months course undoubtedly lead to a corporate spirit between all concerned, the psychological effect of which upon the co-operation between Districts and between Districts

and Headquarters is of immense value. The photograph reproduced on page 142 and the farewell dinner held at the Research Station upon the conclusion of the course give evidence of this spirit. A copy of the menu reproduced on this page shows that at least some of the lectures bore " fruit."

During the last ten years, more than 250 officers selected from all the Engineering Districts have attended Cable Classes held in the Research Section, *i.e.*, an average annual class of at least 25 officers has been required. In addition to such three monthly courses there have been many abridged courses for officers from Colonial Administrations, each lasting from one to three weeks. When it is remembered that since 1920 the capital value of the underground cable system has been increased by about £15,000,000 and is being added to at the rate of nearly £2,000,000 per annum, the need for the adequate training of a staff capable of maintaining such a system in an efficient manner is apparent. All the cable classes to date, however, have been held at irregular intervals, but from the foregoing figures it appears that the adequate maintenance of the cable system necessitates the training of suitable officers at regular intervals.

It is suggested that if this particular branch of training were carried out along the lines of the previous courses in suitable buildings (for which there is ample space in the grounds at Dollis Hill) in which training could be given in other branches of the Department's work, such as that of Automatic Telephony, Telephone Repeaters, Telegraph and Telephone Transmission, etc., the result would prove a sound investment. The station might also be provided with a Hostel for the accommodation of the young officers undergoing training, and might well then rank as an Engineering Training College on a par with the Naval Engineering Colleges and Military Training Colleges already in existence. Admission to the college could be made an incentive to the younger students of the P.O. Engineering Department at present attending Polytechnic Evening Classes.

A copy of the dinner menu is given below.

P.O. ENGINEERING RESEARCH STATION,
DOLLIS HILL.

1930 CABLE CLASS
DINNER,
HELD ON
THURSDAY, APRIL 3RD.

To celebrate the triumphant emergence from a terrifying ordeal.

MENU.

SOUP.

Crême de Moivre.

JOINT.

Roast Beef. Tan Sauce.
Potatoes (B. + B.).
Greens sans grit.

SWEETS.

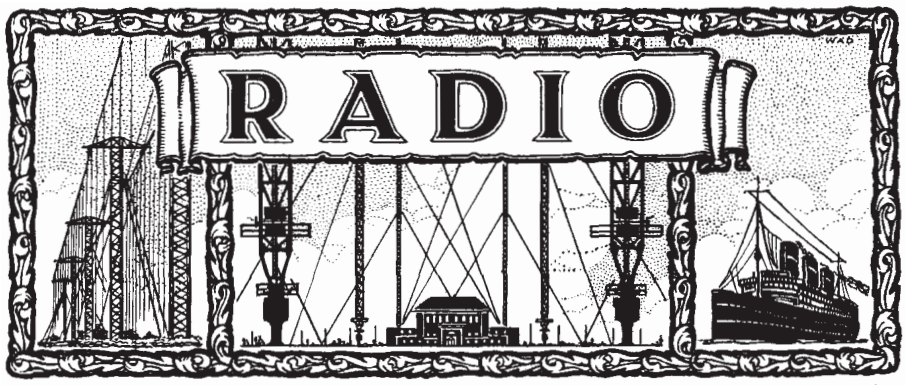
Determinant Puddings
(few).
Split Pears
(no cores).
Raspberries
(plenty).
Cross-whipped Cream.
Cheese and Celery. Café au — j.
Palmerian Oranges.

Joints supplied by Plumbers, of Dollis Hill, and guaranteed to be carefully selected and of best grade.

Catering by D.H. Refreshment Club to B.E.S.A. Specification for Density and Elasticity.

Hydrometers supplied free, but all disputes to be referred to the laboratory.

First Aid at Hut A. *Ambulances 10.15 p.m.*



CONSOLIDATED FUND (No. 3) BILL.

OVERSEA WIRELESS TELEPHONY.

26TH MARCH, 1930.

[*The Postmaster-General's reply to the discussion on the above. Extracted from Parliamentary Debates, House of Commons.*]

THE POSTMASTER-GENERAL *(Mr. Lees-Smith)*: I think it will be for the convenience of the House if I speak now, because the only explanation of the reasons for the Government action has been in answer to a few questions, and I think that probably this matter can be better debated if the full circumstances which the Government had to take into account are stated early in the Debate. I certainly have no complaint to make of the manner in which this subject has been introduced, and I hope to be able to show to the House that the decision of the Government has not been taken on account of any political doctrine, but has been reached on a consideration of national interests. If I can show that, I hope that this subject may become one of general acceptance, and that the Post Office can proceed with its work in the matter.

The late Government leased the beam stations for wireless telegraphy to the Communications Company under certain conditions and circumstances, but they reserved the future of wireless telephony, and I think I shall be able to show that the late Government and the Imperial Conference deliberately refused to give any undertaking that it would use the beam stations for future telephonic development.

That was the position which I found when I came into office, and, after I had been in office only a few weeks—I think it was in August—I received a letter from the Communications Company, from the chairman, followed up, I think, by other communications from Mr. Kellaway and Sir John Pender, suggesting that now the Government should discuss the question of using the beam stations, on payment of a rent, for the development of telephonic services to Canada, Australia, India and South Africa in the first instance, of course to be followed later by general development to the world as a whole. I think it may put the House in possession of the facts in the best way if I tell them what were the considerations which were before my mind at that time, as a layman, without any of the material which has since been accumulated, by which I had to try at any rate to come to some preliminary conclusions on the subject.

There were two alternatives. The first was to use the beam stations. They have the equipment, they have the receivers, they have the transmitters, they have the aerials, and therefore it seems obvious that by combining telegraphy and telephony in, so to speak, one set of apparatus, the most economical results can be achieved.

The other side was this—and it was not reached lightly or carelessly. I visited the great wireless station at Rugby—and I shall be very pleased if any Members of this House will themselves make such a visit—and there I found that there was a great wireless telephone service already in existence, the greatest commercial oversea telephone service in the world, which the Post Office engineers had added to the telegraphic service which was originally initiated there.

The question arises as to whether the advantage of combination in one instrument on the one side would not be outweighed by the advantage of concentration on one site at Rugby with its receiving station at Baldock. What do you find there? There, you have the aerial system pointing to the United States; walk a few yards, and there is the ground plotted out on which there will be an aerial system pointing to Canada; walk a few yards in the other direction, and you have your system pointing to South Africa, a few more yards to India, and a few more yards to Australia. You find already plotted out the whole system by which, in the course of a walk, you can cut across all the lines of conversation from Rugby to every part of the world.

The question, therefore, before us was whether, with the reductions in overhead charges and so on, what might be called rationalisation at Rugby did not give greater advantages than combination in a single instrument at the beam station. In deciding this issue, one had to decide which was the more efficient of the two alternatives offered to the Government, and which was the more economical. On the question of efficiency, an issue arose. The stations of the Marconi Communications Company have developed a system of aerials with very high masts running to about 280 feet in height. The Rugby engineers so far from duplicating the beam stations, have repudiated what is the main feature of the beam station. The Rugby engineers have, on the contrary, preferred the comparatively low masts, and have developed their telephonic aerials on masts of between 120 and 150 feet.

We were met with this claim. The Marchese Marconi and the representatives of the Communications Company argued that there was such an overwhelming superiority in the system of aerials with high masts that no other system would stand by its side. On the other hand, the Post Office engineers advised us that they had deliberately rejected the high mast system on the grounds of expense, and that the high mast aerial system costs roughly about £34,000, but the low mast aerial array costs about £3,500. Although there was a certain loss of power with the low aerial, they had made up for it by developing a very powerful transmitter, so that, taking transmitter and aerial together, the Rugby system gave as much power and, I think, more power than the Marconi aerial array. These were highly technical considerations, and the Government did what I think was the natural and proper thing to do.

We are asked to have yet another inquiry, but I say that no Government has ever inquired into a subject like this more carefully than we have done. There was, first, the Post Office inquiry by their own engineers, and the matter was referred at my request to a Cabinet Committee. The Government are greatly indebted to Lord Thomson, to my hon. Friend the Financial Secretary to the Treasury, and to my hon. Friend the Secretary to the Overseas Trade Department, who, with me, sat on that Cabinet Committee.

The matter, then, was referred to the Cabinet Committee, who decided to refer the matter to two experts, whose authority on this subject has not been challenged since their names were known, and has not been challenged and will not be challenged in this House to-day. We referred this matter separately to the two experts. We told each of them that we were referring it to the other, and, when they had given their independent reports, it was found that they were in such complete agreement, that they finally sent in a joint report to the Cabinet Committee. That gives their views even more weight than they otherwise would have had. The House has the report of the experts in their possession, but, in order to explain exactly the meaning of the questions put, perhaps I may tell the House what was the nature of the evidence and counter-evidence which was put before them. The Post Office engineers, first of all, argued that their system was cheaper; they then argued that, because their system was cheaper—because the aerial low mast system was about £30,000 cheaper than the other — it

possessed a greater degree of adaptability to new inventions than the Marconi system. As they pointed out, wireless telephony changes every month, and you must be ready to take advantage of new adaptations. If you have a cheap aerial system, you can scrap it as new developments occur. If you have an expensive aerial system, you have liabilities which tie you to the old methods.

They further pointed this out—and this is a point of very great importance in connection with the question of hours and guaranteed service for the different Dominions. The Post Office engineers argued that, if you are to guarantee hours of service, and if you are to get a reliable service all over the world, you must have more than one wave-length, because, owing to climatic and electrical disturbances, a wave-length which fades at one period of the day can have its place taken by another. Therefore, they argued, three wave-lengths are necessary for a reliable service. A new wave-length means a new aerial; with a cheap aerial you get a cheap wave-length, and for that reason the Post Office system would give three wave-lengths to each of the Dominions, whereas the Marconi system, with its expensive aerials and expensive wave-lengths, will give only two to most of the Dominions, and to Australia will give only one. These are the questions which were put to the experts. I will read three or four sentences which are most important from their Report:

> "A brief answer to the first question is, therefore, that apart from future development both systems are probably equally capable of providing satisfactory telephonic communication between two points for a given number of hours per day . . . . As regards future developments we think that the adoption of the more elastic aerial system, namely, that with the lower masts"—

that is the Rugby system—

> "would be advantageous since equally satisfactory results could be attained with a smaller expenditure of money."

They also say:

> "There appears to be no reason for supposing that an effective aerial array would need masts over 180 feet in height, and there is no doubt that the cost of masts increases very rapidly when they are over 200 feet in height. The Marconi Company were pioneers in beam development and the Marconi beam stations already erected are handicapped somewhat by this fact. The Post Office system of aerial arrays being carried on lower masts could, therefore, probably be made more effective than the Marconi array at a lower capital cost."

Then, with regard to the question of the number of wave-lengths, they say:

> "A difficulty frequently arises from the varying attenuation of different wave-lengths, and to meet this it is often found desirable to change the wave-length in use according to the time of day. Provision for such choice of wave-lengths is likely to be more cheaply made with a relatively low mast system."

On that Report, the Government felt justified, and were justified, in concluding that there was no such overwhelming superiority on the part of the Marconi system as had been claimed, that, to use very moderate language, the Rugby system was at least as efficient, and that, therefore, we were entitled to proceed to base our conclusions upon other financial and general considerations.

I come to the question of economy. We come to the question of which has been the more economical system. It will perhaps be best if I give the House the pros and cons of that inquiry, in the same way that I did with regard to the inquiry into efficiency. The advanages of the Marconi system, and the economy arising from combination in one instrument I have already referred to and explained. On the other hand, the Rugby system gives great economies. There is economy in the overhead charges and in combining the new services with the service to America and others that may be created; there are economies where all the services are concentrated in one spot, due to our being able to economise in transmitters and to use one transmitter for more than one service. Transmitters are very expensive parts of the equipment.

Finally, the most striking economy comes from the system of land lines. In order to operate the wireless system there must be a system of land lines from a central trunk exchange in London to the wireless stations, in order that the

messages can be taken from London to the wireless stations and there switched into the air. Those land lines are very expensive. By concentrating all your services on one site you save a great many land lines, and, in addition, Rugby and Baldock are a great deal nearer to London than Grimsby, Skegness, Bodmin or Bridgwater, where the beam stations are situated. The beam stations require 4,192 miles of land line circuit, and Rugby and Baldock require 780.

Those are the broad advantages of the two systems. In order to test them by results, it was necessary, first of all, to make an estimate of what the Rugby system would cost, and then ask the Communications Company what rent they would charge, and compare the one with the other. The Rugby system costs, all told, both for the stations and for the land lines, £43,000 a year. The company made an offer containing three alternative proposals. The Post Office—for a reason which I will not enter into—thought the second was, on the whole, the best from their point of view. The second proposal by the company was that they would take a minimum rental of £40,000, plus 10 per cent. of the gross receipts in excess of a certain figure, but in addition to the rental which we were to pay to the Communications Company we had to provide our own land lines, and the annual cost of those would be £20,800. That would make a total of £61,000. If we compare that with the £43,000 which the Post Office system would need, there is a saving of £17,000 or £18,000. But there are greater savings than that, because if the gross receipts amounted to more than a certain figure the company asked for 10 per cent. of them. If the system belongs to Rugby, that comes back to ourselves.

I have said the cost would be £43,000 a year, but I have made no calculation as to savings on overhead charges. If we take into account that we share our site, our plant, much of our service and our labour, with the American service, the £43,000 is reduced to £39,000, giving another £4,000 advantage; and we must further take into account the fact that when we have developed the Canadian, Australian, and Argentine services, then, owing to the economy in transmitters to which I have referred, the saving will be increased by several more thousand pounds, and the average cost of each service will be about £36,000. Adding all these things together, the financial advantage of the Rugby system is somewhere between £20,000 and £30,000.

It was because our inquiries into the relative efficiency of the two systems and their comparative costs showed these results—those were the main considerations: there are others to which I am coming—that we came to the preliminary conclusion that we should be justified in declining the offer of the Communications Company and developing our system by concentration at Rugby and with the receiving station at Baldock. The right hon. Gentleman introduced a number of other considerations which I shall deal with, but I ask any hon. Member who has followed these calculations what other conclusion we could have reached it? If I had been standing at this Box and had asked the House to take into their hands the report of the experts, with its verdict as to the relative efficiency of the two systems; had told them, further, that the Rugby system would save between £20,000 and £30,000 of the taxpayers' money, and then had told them that it was the conclusion of the Government that they ought to allow these services to be leased by the Communications Company, I think I should have been open to the charge that I was sacrificing the national interest to the financial needs of a great commercial corporation.

I will come to the main arguments outside the sphere of economy and efficiency, to which the right hon. Gentleman appeared to pay very little attention. Most of his speech was concerned with other matters. He claimed that there is some sort of moral obligation on the part of the Post Office to use the beam stations, or to give them a trial. I refer to it because he quoted two passages from the Report of the Imperial Wireless and Cable Conference. He quoted Recommendation VIII. That recommendation gives a right, but it imposes no obligation on the Government, to use the beam stations. That recommendation, I may explain, was put in on the recommendation of the Post Office, in order that if we did wish to use the beam stations we should be saved from the danger of having to pay some monopolistic charge. As to the other quotation he gave, a general quotation, he will see if he reads it again that it refers merely to the telegraphic services which were to be handed

over, and has no reference to the telephonic services, which are now under debate. Beyond that I will say that if he will look at the Report of the Imperial Wireless and Cable Conference he will see that this matter was brought before them. It was reported to them that the Communications Company were asking for a guarantee that the beam stations should be used, and they said they were disappointed that the guarantee was being refused, but that they understood the position. That is actually in the Report of the Conference itself. I am very sorry that the late Postmaster-General is not here, owing to illness, because I am satisfied that if he were present he would not contradict what I say.

May I now come to another argument of the right hon. Gentleman? A good many of the facts with which he has been supplied are not correct. He said we refused to provide a service to Canada. The position of the Post Office in that matter has been perfectly frank. We have told the Canadian Government that we think that if they want a good commercial service—if that is all they are thinking of—they will get the best commercial service *via* New York. It has four alternative wave-lengths, and it gives communication to all parts. We have pointed out that if they have a direct service they will lose these four alternative wave-lengths, and will not be able to get to the west of Canada without going through American territory. But we have said that if, in spite of that, they would like a direct service, on account of Imperial reasons, or national reasons, that we are willing to provide that direct service. In the last few days we have received a reply which indicates they will ask for that direct service, and it will be provided by the Post Office, as it would be provided by the Marconi Company.

With regard to the Argentine, we are willing to open a service to the Argentine. We are accused of working through Berlin and Paris. The right hon. Gentleman does not understand that we are awaiting the authority of this House; when we have got the authority of this House, we will open a service to the Argentine within a few weeks. With regard to Egypt, the position there is that there are three companies wishing to obtain concessions in Egypt, and the Egyptian Marconi Company is one of them. We had a letter a few weeks ago saying they were hoping to come to terms, that they were making satisfactory progress with their negotiations with the Egyptian Government. Their managing director called upon us last week and we told him that, subject to the approval of the Egyptian Government, the Post Office would be very happy to open a service with them.

Now I come to the argument used by the right hon. Gentleman the Member for Sevenoaks with regard to America and the United States. I may say, in answer to the specific question which was put to me, that the suggestion that American engineers are employed at Baldock and Rugby is entirely incorrect, because there is not a single one of them employed at either of those stations.

SIR H. YOUNG: My question was with regard to American engineers in the service of the Standard Cable and Telegraphs Company. I am sorry to interrupt the hon. Gentleman, but he has not got the question quite right.

MR. LEES-SMITH: I will now come to the question of American machinery, and ask what the House wishes the Government to do. This is the position. Every Government Department gives a preference to British goods, and the Post Office gives that preference as much as anybody else. British goods are deemed to mean goods produced in this country by British labour. In the contracts for the apparatus which the Post Office requires there are only two companies tendering, namely, the Marconi Company and the Standard Company, to which the right hon. Gentleman the Member for Sevenoaks has referred. The Standard Company is a company financed with American capital. Its works are at New Southgate, Hendon and Woolwich, and it employs several thousand British workmen. The practice of every Government Department and every Government has been not to exclude from their tenders any private company which has a factory in this country and which employs British workers. Is it the policy of the Opposition to exclude from our tenders all those companies which are financed by American capital? Must no orders be given to the Home Counties Electrical Trust?

I would point out that the Standard Company is one of our largest tenderers, and it does £1,000,000 worth of work for us every year in competition with companies like the General Electric Company, and Siemens and Ericsson.

What is the position? Why should not the Post Office follow the same practice as other Departments, and why, when the Standard Company get orders which might have gone to the General Electric Company, or Siemens, do they pass without comment, and when the Standard Company get an order for £20,000 which might have gone to the Marconi Company is made the subject of comment and questions in this House? The Noble Lord the Member for Aldershot (Viscount Wolmer) will remember that he put some questions to me about the Marconi Company. We have not given many orders recently, but there have been three orders during the last two years, and two were given to the Standard Company, and that seems to be what the main complaint is about.

VICOUNT WOLMER: That was before the Imperial and International Communications Company offered to provide the same service to the British Government.

MR. LEES-SMITH: Not at all. Those orders were given under circumstances in which the Marconi Company and the Standard Company both tendered together. At the time when the Noble Lord was at the Post Office either he or his superior officers deliberately, and rightly in my opinion, preferred to give the orders to the Standard Company, because their prices were lower and their quality was higher.

VISCOUNT WOLMER: The hon. Gentleman has not contradicted my statement. I say that those orders were placed by the right hon. Gentleman the Member for South Croydon (Sir W. Mitchell-Thomson) before the Imperial and International Communications Company were in a position to offer the services which they are now offering to the Government, and that cannot be denied.

MR. LEES-SMITH: Those orders were placed at a time when the Marconi Company were in a position to offer those services, and, in fact, did offer them. Since I have been at the Post Office, I have only had one small order to give, and I gave that to the Marconi Company. In order to make the matter clear, I would like to say that I am prepared, in fact I have made arrangements by which, in the future, before these orders are given, the specification for them shall be discussed with the Marconi Company, and any other company that tenders, in order that the difficulties of the past may not occur again in the future. That being so, I hope that we shall cease to have this pressure put upon us, because it is not in the interests of economy or efficiency, and the only result is that articles appear in the newspapers.

What would be the result if the Government gave way to a Press agitation? There are only two tenderers for this particular class of work, and if, as a result of agitation, we cut out the Standard Company, we should give a monopoly to the Marconi Company, and the oversea services would have no alternative source of supply. The right hon. Gentleman the Member for Sevenoaks has told us that the Communications Company has undertaken special obligations. An advisory committee has been dealing with this question, and has drawn up certain specifications, and it is said that for these reasons, among others, we ought to hand over this service to the beam stations. I would like to point out that the Communications Company accepted those obligations at the time in return for most valuable financial rights, which indeed turned out to be so valuable that when it was known that they were to have these obligations there was a boom in their shares on the Stock Exchange. Now that the contract has been made, I entirely repudiate that it is my duty to hand over other financial rights which formed no part of the original arrangement and which can only be handed over at the expense of the nation as a whole.

The right hon. Gentleman the Member for Sevenoaks made a good many remarks about the Post Office, and he re-echoed what has happened in the Press during the last nine months. Ever since I have been Postmaster-General there has been a steady stream of attacks and criticisms of the Post Office, in which the Marconi Company has taken a very considerable share. Now this great issue has been brought before the House and we find that the same interests and the same newspapers that have been attacking the Post Office for the last nine months are urging that the Post Office should hand over these great national services to this company, and they are leading the way in this attack. Let the House remember the task which the Post Office has to perform. The Post Office is a great State Department, and I repudiate the notion that it should be placed on an equality with the

Communications Company, because that is a most improper and unconstitutional doctrine.

SIR H. YOUNG: I did not put the Company on an equality with the Post Office, but I pointed out matters of similarity.

MR. LEES-SMITH: The right hon. Gentleman dealt with it as a public utility company, but there are many kinds of companies. The Communications Company is not like the British Broadcasting Corporation or the Port of London Authority which make no profit at all. It is not that sort of public utility; it is a company in which profits play a very important part, and its shares are dealt with on the Stock Exchange. The Post Office is a great State Department which is represented in this House, and, as the faithful representative of this House, it has to enter into negotiation with great and powerful financial interests, and consequently it is bound to create hostilities and antagonism if it faithfully discharges its duty. I do not ask for any favours, but I think the hands of the Post Office are weakened in defence of the public interest if when it creates those hostilities its action is to be received with hostile criticism in the Press. The Post Office cannot defend the public interest unless it gets some sympathy and understanding, if not from the Press at any rate as a last resort in this House.

During the last three or four days there was put into my private door a letter written by Sir Ambrose Fleming, long associated with the Marconi Company, and that letter which was supported by a leading article in the *Times* contained abuse of Post Office engineers, and stated that the Post Office engineers suffered from ineptitude, sterility, and stagnation. Stagnation indeed, when the very reason that we are holding this Debate is that the Post Office engineers have developed at Rugby the greatest commercial telephone service in the world, a service which carries 100 messages per day, a service which carries more commercial messages than all the other oversea telephone services put together, a service which makes thousands of pounds a year profit, and which, by linking America to Europe, enables the subscribers to get into communication with 90 per cent. of the telephone users in the world. Stagnation indeed! The Post Office engineers have built at Rugby a service which independent experts pronounce to be the equal to-day of their competitors, and likely in the future to drive their rivals off the field. I should like to take this opportunity—it is not very often that I get the opportunity—of expressing my thanks to and my appreciation of the staff of the Post Office for the inventiveness and initiative that they have shown; and I ask the House, by authorising this new development this afternoon, to show their appreciation by now giving them the power to go forward with the ordered and full development of this great new national service which their patriotism and their enterprise has provided for the State.

MR. PYBUS: I intervene in this Debate with considerable diffidence, because if it is based on the subject on which it was ostensibly to be based, the question is far too technical to discuss in this House. If there is no other consideration than the technical question, I cannot understand the wisdom of raising the matter here. I have spent most of my life as an electrical engineer, and I am bound to confess that the subject in its higher reaches is certainly too profound for me. I admired the courage and determination of the right hon. Gentleman the Member for Sparkbrook (Mr. Amery) in putting over so much technical information with so much emphasis. Hon. Members will be well-advised to keep off the technical side of this subject until they are quite sure that it is on a technical question that this Motion has been put forward. Hon. Members should not worry themselves about high aerials or low aerials. I cannot understand why, when one department takes a departmental decision to place a contract in a certain direction, it is the subject of half a day's debate in this House, while when nearly every other Department makes a decision as to where a contract shall be placed such decision is accepted by the contractors and nothing more is heard of it.

What is the real issue? The right hon. Gentleman the Member for Sevenoaks (Sir H. Young) in his speech maintained a very high note. I felt a little nervous about following him as he laid down the dangers for the Empire in the course which the Postmaster-General proposed to take. I consider that the Postmaster-General very kindly and equally courteously demolished those arguments, and reassured the right hon. Member for Sevenoaks that now we

can treat this matter as a matter of business. What has really happened? Somebody wanted to sell something to the Postmaster-General, and he replied, " I thank you, but I think that I can do it better myself." That is an answer which I have often heard in business. My only regret is that when, in the old days, I lost a contract from the Government, I was unable to secure such excellent publicity and such persuasive advocacy. The truth is that the Debate is not a technical Debate at all. There are always two ways of doing everything. What the technical report of the experts says is, that of the two ways offered to the Government, and of which the Postmaster-General has the choice of alternative, both, or either, of them will do the job. I think that those who have brought the name of Marconi into the discussion do him an injustice. It would be a very grudging House of Commons which did not accord to that great scientist a full meed of gratitude for what he has done in developing this great science from its very beginning. He ranks alongside Stevenson and James Watt. But in the days of Stevenson and James Watt inventions were not floated for millions of money, and consequently the Postmaster-General, or whoever would be placing a contract before Parliament at that time, would not find himself confronted with the difficulty of having to give up all development on his own account because he had handed that development over to somebody else.

I am not attacking the Marconi Company or the International Communications. I am sorry in a way that it has not been possible for this business to have gone to the Marconi Company, but I refuse to allow questions of Empire, introduced quite illogically, to intrude in what is nothing more than a straight business proposition. I consider that the Postmaster-General acted with unusual care. I cannot see the First Lord of the Admiralty acting with the same care when he decides to adopt a gun-mounting or a fuse and refuses to have it developed by Vickers-Armstrong. The Postmaster-General appointed two experts. Their report is as clear to the ordinary man-in-the-street as any report of so highly technical a nature could be. He then put that report before the Cabinet. The Cabinet approved that report. I cannot imagine how the placing of any contract or any concession, after assessing it in that manner and after it has received the full support of the Government, can be questioned, unless you wish to question the entire integrity of the Government.

Why should not the Post Office develop this system? The Post Office engineers in the past have had a great record of service of invention and of enterprise. Those of us who know anything of the Post Office realise that many devices which are, in the first instance, invented by somebody outside, are improved by somebody inside the Post Office, and it is very difficult to assess what is done by the Post Office and what is done by somebody else. I should be very sorry if there was a feeling in this House that the Post Office were not entitled to a research staff equal to the work which they would have to undertake. I consider the mere fact that there are masts erected in one part of the counrty by the Marconi Company and other masts erected by somebody else really does not matter one bit. In ten years' time, possibly, there will not be one mast of either type. The fact is that the whole business, the whole art, is in the same stage of development as the Rocket and the subsequent steam engines were. Having supported the Government in their view that they should carry out telephonic communication with wireless in this manner, I should like to plead that if they intend to set up a Department under the Government they should develop alongside Marconi interests and other progressive interests in order to get the best for the country. I hope that in asking for the best brains for Government service they will, at any rate, reward them reasonably and at a fair rate. The greatest weakness of the present Government is in securing for the State proper research for that Department. The chief engineer of the Post Office is rated, I think, at a basic salary of £1,500 a year and his Department hand over £8,000,000 to the State. This sort of thing will not help in the proper development of research by the Government.

I hope that the Postmaster-General will proceed calmly and serenely on his way to do what he feels is best for the country, and that he will not allow himself to be disturbed or his staff diverted from their object by attacks from one side or the other. I trust that if that chance is given to them, the quarrel between the opposing interests may yet die down, and that we shall find

the British Government marching side by side with the Marconi Company, as they should do, and everybody getting the best out of research. I have pleasure in supporting the Postmaster-General.

MAJOR CHURCH: I would like to support the hon. Member for Harwich (Mr. Pybus) in the claim which he has made on behalf of the Post Office to try to put an end to this somewhat distressing quarrel between two great corporations, one possessing the whole backing of the State, and the other a private corporation, which had the support of the State through the late Postmaster-General ending in an agreement finally arrived at between the company and the present Postmaster-General. I deplore, as I expect most Members of this House deplore, the curious way in which the Communications Company advanced their claim to submit this matter of telephonic rights in trans-oceanic telephonic communication to an impartial inquiry. I can imagine no impartial inquiry into such a matter which does not contain experts on its committee, and I can imagine no experts appointed to such a committee who would not either be in the employ of the Communications Company or in the employ, directly or indirectly, of the State. I am not impugning for a moment their good faith in the matter. I am only pointing out how difficult it would be to convince anybody among the general public of the complete impartiality of the experts on either side. I should also like to point out the difficulty which any of us laymen, or any laymen sitting on such a committee, would have in coming to a common opinion with regard to the rival claims, or the rival opinions, if there were rival opinions, of the so called impartial experts.

If you take the development of the wireless transmission services in this country, it is obvious that a certain amount of work has been done by the Marchese Marconi and other scientists. In recent years the whole of the developments have been in the hands of the Marconi Company, or two or three departments of the State. I refer to the Post Office, the Admiralty and the Air Force. The experts of these various services, including the Marconi Company, have been gathered together on a Radio Research Board. It has been suggested in the Press during the past few weeks that the Post Office and the Government as a whole have not at their command the services of men such as are at the command of the Marconi Company, or, shall I say, of the Imperial Communications Company. If hon. Members make any reference to any work on wireless or to recent research work, they will find that the Government experts are in the van of progress. It is true, as the hon. Member for Harwich said, that they are not remunerated in proportion to their intrinsic worth to the State. That is a matter which he and his fellow commissioners on the Royal Commission will probably be able to put right. One has only to refer to the work of the Post Office in recent years to realise how great a prejudice there must be in the minds of certain outside interests which may, rightly or wrongly, be in opposition to the Post Office experts. For example, there was a letter in the Press the other day from Sir Ambrose Fleming, a great inventor. One does not accuse him of prejudice and one is not imputing motives to him, but it is a fact worth recording that the prolongation of his patent for the thermionic valve was successfully opposed by the Post Office, and one always regards as suspect letters from people who regard themselves as penalised by the advice given by Government experts on such matters.

Right hon. and hon. Members opposite who have taken the trouble to visit Rugby—I am one of them—have probably been surprised at the amazing progress that has been made in a very few years with regard to wireless telephony. I am credibly informed, shall I say authoritatively informed, that when the possibility of wireless telephony was before the Inter-Departmental Committee eight or nine years ago, the experts from the Marconi Company expressed the opinion that there was not the slightest possibility of that service ever being developed. It is true that experts change their opinions, but here is the fact that eight or nine years ago the opinion of the Marconi experts was that there was no future for wireless telephony, based on the knowledge existing at that time. The Post Office showed a considerable degree of foresight in the matter, and we cannot blame our Post Office engineers for not being given that full glare of publicity which almost invariably attaches to experts employed, and not always employed for the best of motives by private com-

panies. Eight or nine years ago the Marconi Company's experts definitely said that there was no future for long distance wireless telephony, but the Post Office went forward. It is true that when the Imperial Communications Committee were considering the future of imperial communications, they reserved to the nation, through the Post Office, the right to develop these services, and it is equally true that the Imperial Communications Company wished to have the privilege of working the services, but at that time they were not in operation; they were in a purely experimental stage. What is the position at the present time? We have a receiving station at Cupar and another receiving station at Baldock, the station at Cupar being used for long-wave reception and that at Baldock for short-wave reception. With the two stations we are able to maintain wireless telephone communication with America for the whole 24 hours of every day in the year. It is not claimed—certainly I have not heard that it is claimed—by the Imperial Communications Company that they can operate their system for 24 hours in the day. That is one very essential factor, and that is done by a combination of the long-wave system and the short-wave system. As the Postmaster-General has said, the short-wave system has this advantage, as operated by the Post Office, that there is the choice of three wave-lengths, 15, 24 and 32 which can be operated. One wave-length may be better for one period during the day, during a certain state of the atmosphere, and another wave-length may be more suitable for another period of the day. The fact remains that we have a 24 hours' service, and it happens to be a very lucrative business.

I was informed, and I believe that it is an under-estimate, that the number of messages per month, according to the average for the last three or four months, has been 1,200, with an average duration of six minutes for each message. In other words, we have a revenue, assuming that that average can be maintained throughout the year, and apparently it is on the increase, based upon £9 for six minutes—that is half the total revenue, because the total revenue will be £18, half of which will have to go to the company on the other side—of something approaching £130,000 for a capital expenditure on the station—and this is worth remembering—of £500,000. It is quite conceivable that in the not very distant future when we have developed the beam service to Australia—and that is in the immediate realm of probability—and to India and other countries, indeed, it is fairly obvious, that with a very small additional expenditure the State will derive a very considerable revenue from its wireless telephony services.

I am reminded that when the wireless telegraph services were handed over to the Imperial Communications Company, a system which cost the Post Office £160,000 to develop was actually receiving each year £160,000 in revenue; in other words, the revenue from the system was practically equal to the capital expenditure, not because the Post Office wished to keep up their prices but because of an agreement arrived at between the Post Office and certain cable companies not unduly to lower their prices for overseas transmission. As a going concern that has been handed over to the merger company. It is sometimes suggested that the Post Office is very much behindhand. The charge was made by Sir Ambrose Fleming in his letter to the *Times* that the Post Office when they had the cables, or certain portions of the cable system, under their control, did not introduce the new permalloy system. That system had not been in existence very long then. If that system is what it claims to be, and I understand that you can send messages over it at about ten times the rate, and even more, than over the existing Atlantic cables or over any ocean submarine cable, one wonders what the merger company, the Imperial Communications Company, has been doing all this time in continuing to use cables which are completely obsolescent. We need more cables.

I would like to ask the Postmaster-General in regard to the development of international wireless telephonic services, whether the agreement with the Imperial Communications Company in regard to telephonic services gives to that company the right in respect of all messages transmitted over submarine cables, or is that right still reserved to the nation? If not, I can see a tremendous future for the Imperial Communications Company if they will only take a bold step and lay some of the new cables, which can be manufactured in this country and certainly would

be manufactured in this country. The Permalloy has its counterpart in a new alloy discovered in this country possessing the same properties. Permalloy was an American invention. It is within the realm of possibility that we shall be able over these new cables to send seven or more messages simultaneously—not telegraphic messages but telephonic messages. We shall be able to use one cable for transmitting seven telephone communications at the same time. That would conceivably make a tremendous difference to the development of wireless telephonic services.

The advance of science, as the hon. Member for Harwich said, in this particular field of research cannot be gauged to any degree of nicety at the present time. We are discovering new things every day. Our Government scientists, under-paid though they are, apply themselves with tremendous energy and enthusiasm to the task of keeping alight the lamp of research. They have made a number of remarkable contributions to the growth of this particular science. Some of them are employed by the Post Office. No Government scientist gets the same amount of publicity as the scientists outside, and there is a tendency on the part of the general public, because there is not constant advertisement by the State of these services, to get the impression that the Government scientist is somewhat inferior to the scientist employed outside. That is an entire misconception. We have men in the Government telephone service who stand high among their fellows, and the State has every reason to be proud of the service it maintains, whether by the Post Office, the Admiralty or any other Department. One need not enumerate the many contributions made by Post Office engineers to the advancement, particularly of the technical side, of wireless telephony in the past few years. The results they have achieved are well known throughout the technical and scientific world. But I want to say this in regard to the Post Office Engineering Department: it is not a scientific Department.

Under the Haldane Report a definite line of demarcation was laid down between what is fundamental and applied research. It is the business of the Post Office engineers to apply the researches made in universities and laboratories throughout the world; to keep abreast of all modern achievements in science and to apply them. Their primary function is not to make discoveries for themselves, and any sneer or suggestion that they are lacking in competence is entirely unfair. They are performing their functions only too well for some of the outside interests. They are keeping themselves so well abreast of modern developments, that, apparently, this country is leading the world in the question of trans-continental telephonic service. Anyone who has been to Rugby or has taken the trouble to realise how delicate a machine there is in being, how complicated is the machinery, and how easily it can be put out of order, not only by faulty operation but by faulty research work, will realise the tremendous strides forward that have been made by the Post Office in comparatively few years.

There is another point with regard to telegraphs. When you hand a telegram over the counter for overseas or this country, there is no question of getting in touch immediately with someone at the other end of the wire. In dealing with telephones you have a different proposition, and one of the reasons why I wish the Imperial wireless telephone service and cable telephone service to be kept in the hands of the Post Office is that such a policy would ensure an absence of friction. If you have two entirely different concerns, one an outside concern existing in the interests of its shareholders and operating through the Post Office, as is suggested, and anything goes wrong with the service, the blame will be put on the Communications Company by the Post Office and by the Communications Company on the Post Office. It is much better, when you are dealing with telephones and the possibility of a breakdown due to the personal factor—and we know that breakdowns of that kind are not infrequent—that you should have control centralised in one institution, which has built upon a somewhat unskilled foundation a great telephone service not only for this country but for the whole world.

NOTES & COMMENTS

WE publish elsewhere in this issue reports from Hansard, which state the Post Office case in the debate in the House of Commons on the recent proposed acquisition by a public company of the Inter-Dominion telephone service. Much could be said on the subject, but it is considered that our readers should have at least a verbatim report of the Government's point of view. We are not concerned with the political aspect of the situation, but as engineers we are deeply interested in the technical and economic side, and it is gratifying to be able to announce the complete success of the section whose job it was to install and bring the service into operation. On the 30th April a public telephone service was opened between this country and Australia. Communication was available at the opening between telephone subscribers here and in Melbourne and Sydney, but the facility has now been extended to Brisbane on the other side and to western European countries generally. Transmission is effected from Rugby on a short-wave system of some 25/32 metres and received at La Perouse near Sydney; the corresponding points in the other direction being Tennants Hill, Sydney and Baldock, the main short-wave receiving station on the Baldock-Royston road. The opening talk between the British and Australian Premiers on the 30th April was broadcast by the B.B.C., and was very successful, barring a short failure of the broadcast transmitter. The difference in time between this country and Australia militates against the growth of traffic, but in spite of this the service is being taken up remarkably well. Conditions for operating telephone service to South Africa are much better and it is to be hoped that the authorities there will take steps to come into line.

A service has also been opened to the principal cities in the Argentine, Uruguay and Chili *via* Madrid and Buenos Aires radio, a limited service to Rio de Janeiro *via* Paris and one to Java *via* Amsterdam. Ship and Shore services are also in operation between certain large transatlantic liners and Rugby-Baldock.

TELEPHONE RATES COMPARISON:

NEW YORK AND LONDON.

While Britain has a lower telephone density than the U.S.A., she enjoys cheaper calls. Noteworthy statistics prepared by the Engineering Department of the British Post Office show that, contrary to the opinion very generally held in this country, both business and domestic telephone rates are considerably higher in New York than in London. Rates throughout America tend to vary more than in this country, as the local services are in the hands of many independent companies. British rates are, as nearly as may be, uniform.

In the inner areas the business rates are:—

No. of Calls.	New York.	London.
	£ s. d.	£ s. d.
180	14 7 6	8 15 0
900	14 7 6	11 15 0
1800	22 16 3	15 10 0

In the outer areas the domestic rates are:—

No. of Calls.	New York.	London.
	£ s. d.	£ s. d.
180	10 10 0	6 5 0
792	10 10 0	8 16 0
1692	18 10 9	12 1 0

It should be understood that the New York rentals of £14 7s. 6d. and £10 10s. od. include, respectively, 900 and 792 free calls, the subscriber subsequently paying per call at a decreasing rate as the number increases. The London local rate is, of course, 1d. per call, and its advantage therefore, while considerable at the lower calling rate, becomes even more marked as the calling rate becomes really high, for each additional call adds nearly twice as much to the New York bill as to the London bill.—*Electrical Review*, 2nd May, 1930.

STATES OF GUERNSEY TELEPHONE DEPARTMENT.

Mr. E. H. Bennett, Manager-Engineer of the Department, has sent us a copy of the Balance Sheet for the year ended 31st December, 1929. The number of subscribers' lines shows an increase for the year of 104, being now 3,740. The gross revenue for the year was £20,597, an increase of £1,378, but the net profit is down by £36. The department offers subscribers four tariffs—A, private houses, £2 10s. per annum with 120 free calls, afterwards 1d. per call; A, business premises, £3 os. od. per annum with 240 free calls, afterwards 1d. per call; B, £3 per annum and ½d. per call; and C, £6 10s. od. per annum and 3,200 calls without further payment. The number of subscribers paying these tariffs is as follows, the figures for the preceding year being given in brackets: A, private houses, 1,011 (955); A, business premises, 1,883 (1839); B 445 (437) and C 401 (405). The metallic circuit wire mileage, overhead, amounts to 2,385 miles, a decrease of 43, while the underground reaches 4,908½ miles, an increase of 22¾.

LARGE EXPENDITURE ON TELEPHONES PLANNED IN BRITISH COLUMBIA.

Large capital expenditures on telephone system in the Province of British Columbia this year are indicated in the announcement that the British Columbia Telephone Company, Inc., is planning the expenditure of $5,000,000, made up as follows:—Buildings, $690,000; central office equipment about $1,500,000; subscribers' station equipment, $180,000; outside exchange plant, $1,560,000, and toll line construction, $1,070,000.

MR. DANE SINCLAIR.

Mr. Dane Sinclair passed away at his residence, "Oakwood," Weybridge, on May 6th, at the age of 78 years. He had been in failing health for some time past. He leaves a widow, four daughters and a son, Mr. D. Johnstone Sinclair, who is a director of British Insulated Cables, Ltd., of which company his father had been chairman since 1927.

Mr. Dane Sinclair was born in 1852 at Caithness, and the whole of his life was spent in connection with telegraph, telephone, cable manufacturing, and other associated interests. His electrical career commenced in 1872 in the telegraph department of the North British Railway, and three years later he was sent with several other men to Japan for work in the erection of telegraph lines. He was appointed Inspector of Telegraphs by the Japanese Government, and in recognition of his valuable services the Mikado conferred upon him the Distinguished Order of the Rising Sun, Third Class. When he returned to this country after five years in Japan he was appointed engineer to the National Telephone Company for the Glasgow district. Shortly afterwards the three principal telephone companies in Great Britain were amalgamated into the large concern which retained the name of the National Telephone Company, and Mr. Sinclair was asked by the directors of that company to furnish a comprehensive report on the equipment and working of the whole enlarged system. His report formed the basis upon which a complete reorganisation was carried out, and it laid down the lines of policy on which the operations of that company were successfully conducted. Mr. Sinclair became London manager of the company in 1892 and from that year until 1902 he was engineer-in-chief of the entire system. That position he vacated in order to take up the post of general manager of the

British Insulated and Helsby Cables, Ltd., at the invitation of the late Mr. James Taylor. From the year 1902 down to the day of his death Mr. Sinclair was associated with the British Insulated Cables, Ltd., first as general manager, later as general manager and director, and the great growth made by the company is a matter of general knowledge in the industry at home and in the markets abroad. Its record during the past few years include important railway electrification work in India and Australia, the Mid-Scottish Grid, and other undertakings. He became chairman of the company in 1927 on the death of Mr. James Taylor, J.P., and combined the post of managing director with the chairmanship until July, 1928, when in view of his many years of strenuous work he relinquished the more active duties of managing director in favour of Mr. G. H. Nisbett. In the development of the Automatic Telephone Manufacturing Company, which was originally a subsidiary of British Insulated Cables, Mr. Sinclair displayed great experience and skill. On his recommendation the Strowger patents were acquired, and he was active in promoting the use of this system for automatic telephone equipment in many towns in Great Britain and in various foreign countries.

A correspondent writing to the *Times* pays him a high tribute for his kindly disposition, integrity and genuine character, which endeared him to a large circle of friends. " His," says the writer, " was a nature unspoiled by prosperity, and he proved a ready friend to all in adversity." We are sure therefore that we shall be expressing the feelings of the whole electrical industry when we offer our sincere sympathy to his widow and family in their bereavement. The funeral took place at Wick, Caithness. A silent and touching tribute was paid to Mr. Sinclair's memory when the cars conveying the remains and the mourners halted for a short time outside the company's offices, Surrey House, the Embankment, on the way from Weybridge to Euston Station.—*Electrical Review*, 16th May, 1930.

Everybody in the world to-day thinks he can build a wireless set and each builder is convinced that the results of his combination of receiver and loud speaker are the best ever produced, although many an able radio engineer has had his pride humbled by his wife blandly asking him if she should not get young Johnny across the road, who has built such a fine set, to come and assist him out of his difficulties. The number of experts is legion, but they are not always disinterested, so-and-so's coils, such-and-such a condenser are necessary to complete the ideal set. One of the Radio Section engineers, who has been directly engaged in the construction of receiving sets, will in our next issue discuss the present position of the reception of broadcast music, talks, etc., and point out the advantages and disadvantages of the several systems of high frequency amplification, rectification and audio amplification now in use by the best manufacturers. The general public is not aware of the part played by the Department in this broadcasting business, beyond the fact that wireless licences are issued at post offices. Much of the S.B. work is carried on line circuits, and our latest cables are being fitted with screened pairs or quads for broadcast operations, to secure a minimum of interference and with high cut-off points for music transmission.

We have been charged sometimes with making the Journal too mathematical, too highbrow in character for the ordinary working man, be he engineer, inspector, skilled workman or youth-in-training. This may be true at times, but the fact remains that certain aspects of the subject of electrical communications cannot be properly treated except by the use of mathematics, and it has been our constant aim to maintain the high standard of the magazine and to render it as useful as possible to our readers. The introduction of a Telephone Transmission examination by the City and Guilds authorities has created a demand for teaching courses on the subject, which is being catered for at many of the technical institutes. Mr. W. T. Palmer, of the Research Section and a lecturer at the Northampton Polytechnic Institute, Clerkenwell, has agreed to contribute a series of articles on a " Guide to Telephone Transmission Theory " which will begin in our October issue. Mr. Palmer will start from first principles and will lead up to and cover the syllabus of the above examination, and perhaps farther. The series will of course be

mathematical, but we need not fear criticism of our contents bill on this score—the material will be useful to most of us and especially to the younger men with ambitions to go higher.

We have to thank all ranks of the Engineering Department, from the Superintending Engineers down to Youths-in-training, for the hearty support they have given to our appeal for increased support. The result is most gratifying, since the appeal brought in some 1,600 additional subscribers and has brought our circulation well over 6,000 copies per quarter. We are not content, however, even with this increase; a staff of 30,000 men should do better, as one journal among six men does not go very far. To explain this ratio it should be mentioned that over 1,000 copies go overseas quarterly. Next year, when we hope to reduce the price to one shilling, the number of subscribers should show another twenty-five per cent. increase, at least.

HEADQUARTER'S NOTES.

EXCHANGE EQUIPMENT.

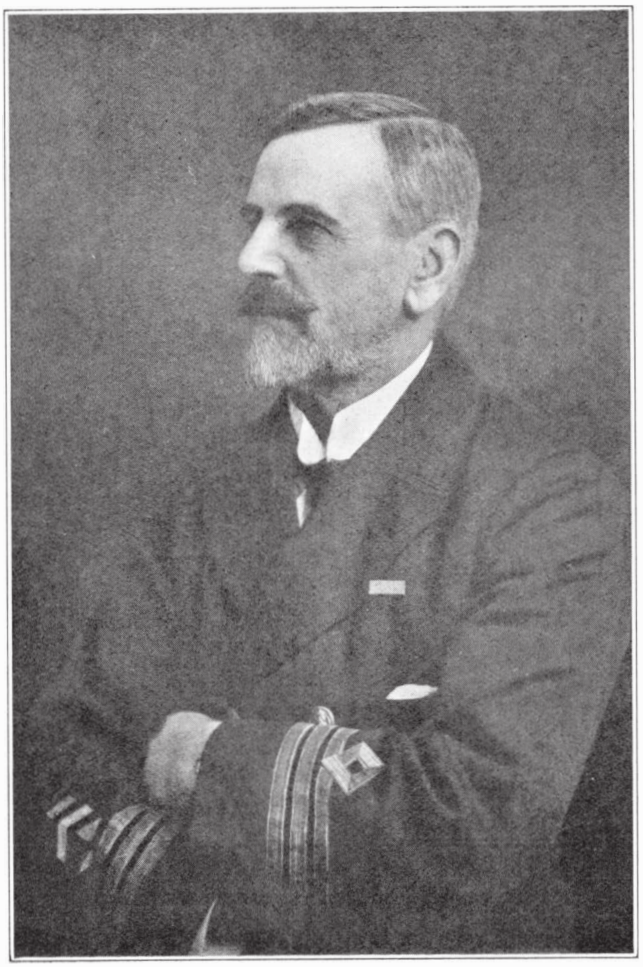
The following works have been completed:—

Exchange.	Type.	No. of Lines.
Moss Side	New Auto.	1780
Middlesbrough Area (4) ...	,,	4200
Fulham	,,	7500
Portobello	,,	700
Temple Bar	,,	8000
Amherst	,,	3600
Primrose Hill	,,	7000
Collyhurst	,,	1950
Terminus	,,	M.F. only
Maidstone Area (8)	,,	3200
Granton	,,	1220
Oxford	Auto Extn.	Re-arrangements
Cowley	,,	200
Headington	,,	200
Arkwright Notts.)	,,	760
Grimsby	,,	550
Sherwood (Notts.)	,,	200
Castleton	,,	100
Whitworth	,,	100
Bishopgate	,,	100
Maida Vale	,,	Re-arrangements
Bath	,,	Obsn. Equipt.
Great Moor	New Manual	900
Loughton	,,	1020
Bradbury Agnew	P.A.B.X.	40
Lewis Berger	,,	30
Colgate Palm Olive	,,	30
Kiaer & Co.	,,	20
Lighting Trades	,,	30
Shell Mex	,,	30
French & Sons	,,	30

Orders have been placed for the following works:—

Exchange.	Type.	No. of Lines
Southall	New Auto.	1700
Ayr	,,	1780
Prestwick	,,	520
London Operators' School ...		—
Temple Bar	Auto Extn.	100
Bishopgate	,,	100
Edgware	,,	1500
Ipswich	,,	300
Rochdale	,,	300
Crawley	,,	Re-arrangements
Sanderstead	New Manual	620
Gof Stores	,,	1650
M.G. Cars	P.A.B.X.	200
Reading University	,,	30
Kiaer & Co.	,,	20
Ipswich	,,	20
Strachan & Co.	,,	20
British Tube Mills	,,	30
B'ham Corpn. (Mental) ...	,,	20
Constructors, Ltd.	,,	20
Crowe & Co.	,,	20
C. Lloyd	,,	20
Emmanel College	,,	30

CAPT. HENRY FRANK BOURDEAUX, O.B.E.



CAPTAIN HENRY FRANK BOURDEAUX, O.B.E.

THE retirement of Captain Bourdeaux on April 30th, 1930, breaks an association of this name with the Submarine Branch which has been continuous since the transfer to the State of the Submarine Telegraph Company in 1889. Captain H. F. Bourdeaux's father was the first Post Office Submarine Superintendent, and his brother was his immediate predecessor in that position.

His early life at Dover undoubtedly gave him a predilection for the sea, and the hardships of old sailing ship days did not alter his determination to be, if not a "sailor bold," then a competent experienced navigator. In fact Captain Bourdeaux, when relating those early experiences had little to say of the hardships, but much of the wonders of the life and the good fellowship which existed. He did not enter the Post Office service until he was 27 years of age, when, with junior rank, he joined the old cable ship "Monarch" which, incidentally, it will be remembered, was lost by enemy action off Dover in September, 1915. Fortunately our friend was not then on board. His war services around our coasts were, however, sufficiently vivid, exciting and dangerous. Indeed, it is not known generally, even in our own Department, what a risky job it was during the war to be engaged on a Post Office cable ship. Overseas communications were of course vital and these were maintained with a disregard for mines and torpedoes and with a high sense of duty which perhaps it may be said received less than due recognition when honours were distributed. Captain Bourdeaux, however, was fortunate to receive the honour of the O.B.E. and special commendation for his good work.

After the Armistice, Captain Bourdeaux took over the arduous duties of Commander of the new "Alert," combining the duties of Navigating Commander, Cable Engineer and Electrician. This was, at that time, a tough proposition, as the original officers and permanent crew of the old "Monarch" and "Alert" were dispersed and divided between four or five auxiliary ships temporarily fitted up as cable ships, leaving Captain Bourdeaux with only a skeleton trained crew to assist him to do his part in overtaking the heavy arrears in submarine cable work.

On the retirement of his brother, Mr. John Bourdeaux, he became Submarine Superintendent in April, 1922, being the first officer of that rank to be placed on the Headquarters Staff under the Submarine Reorganization.

One might have thought that under these circumstances, Captain Bourdeaux must have felt at times like a "fish out of water," but by his qualities of tact, unfailing courtesy and cheerful disposition, he soon endeared himself to his colleagues at Headquarters and at the same time retained the respect and affection of the Submarine Staff for whose work and welfare he remained responsible.

As head of the Submarine Branch of the

British Post Office, Captain Bourdeaux was, of course, well known to submarine cable engineers in many countries and his expert advice was frequently sought.

On May 27th, colleagues and friends gathered together to say farewell and Godspeed. Mr. Shaughnessy in happy vein, supported by other members of the Staff, expressed kindly thought and appreciation of Captain Bourdeaux's many fine qualities and subsequently handed to him a gold repeater watch and an illuminated autograph album as a tangible expression of this appreciation. To Mrs. Bourdeaux was sent a beautiful inlaid Indian tray.

We regret our friend's departure, we shall miss his outstanding characteristics of friendliness and cheery optimism, but that he will be happy in his retirement we can have no doubt.

ENGINEERING DISTRICT NOTES.

LONDON DISTRICT.

Exchanges, Exchange Lines and Stations.

At March 31st, 1930, there were 391,359 direct exchange lines in the London area and 659,318 stations, an increase during the quarter of 8,003 exchange lines and 13,379 stations. At the same date the total number of exchanges in the area was 136, of which 23 were automatic.

Eight automatic exchanges are now being installed, the total initial equipment of these exchanges being 30,500 lines. The ultimate capacity of these exchanges is, of course, very much greater. In addition there are thirteen buildings being erected to accommodate automatic exchanges.

In connection with the issue of the March telephone directory, 17,000 lines were transferred from one exchange to another. These transfers are necessary on account of the establishment of new exchanges which necessarily serve areas which were previously served by other exchanges. A similar number of transfers is necessary every six months, but although a certain amount of inconvenience to subscribers is unavoidable, the transfers give rise to very few complaints. This is due to the systematic preparatory work and the care which is taken by the Traffic and Engineering Departments to reduce the inconvenience to a minimum and to deal promptly with enquiries regarding changed numbers, etc.

Reconstruction of Toll Exchange "B."

Some years ago it became necessary to establish a separate exchange to deal with the traffic on short trunk or "Toll" circuits in order to allow room for the expansion of the traffic on long trunk circuits. The exchange thus established is situated in Norwich Street, Holborn, about three-quarters of a mile from the main trunk exchange. After the transfer the growth of traffic on the Toll circuits was very rapid and it subsequently became necessary to divide it so that only the traffic incoming from towns in the Toll area was dealt with at Norwich Street, which was renamed Toll "B," while traffic outgoing to towns in the Toll area was dealt with at a new exchange established at G.P.O. South and named Toll "A."

It has now been necessary to convert the positions at Norwich Street which were formerly used for outgoing traffic so that they can be utilised to deal with the ever increasing volume of incoming traffic. This work is being carried out by the Sectional Staff and comprises the following items:—

- Recovery of wiring on 68 operators' positions and provision of new wiring. Of this number, 29 will be provided with jack-ended circuits and the remainder with plug-ended order wire circuits. All positions will be provided with additional cord circuits.
- Outgoing multiple extended by 980 jacks over all positions.
- Provide 40 additional order wires on all positions, including those which are at present working.
- Extend the test jack field on the test desk by 500 jacks.

The work is well advanced and some of the

rewired positions will shortly be brought into use.

Radio Channels.

The number of channels for radio service continues to increase. In addition to the four channels for which equipment was installed in the new radio room on the 1st Floor, G.P.O. South, equipment has now been provided for two further channels and the preliminary work in connection with the installation of equipment for four additional channels is now proceeding. When this is completed, a total of 10 channels will be available.

This work is also being carried out by the Sectional Staff.

Removal of Record Distribution Positions at G.P.O. South.

The above mentioned positions, at which requests from London subscribers for Trunk connections are switched to Record tables on another floor, were originally accommodated on the main suite of positions in the Trunk exchange, but their removal to the same floor as that on which the Record tables were accommodated became necessary in order to provide accommodation for additional radio channels owing to the rapid expansion in the radio traffic.

The circuits are of a special character and standard switchboards were not suitable. Three No. 10 stripped sections were used and wired on the spot. Each section is provided with 33 lines to " Record " operators and is wired for 40. The suite will accommodate 600 " Incoming " record circuits.

The work had to be carried out by the local staff at high speed and to proceed continuously owing to the necessity to provide the additional Radio Channels at short notice. The transfer was effected at 6 o'clock p.m. on an ordinary week-day without trouble.

Teleprinters for Race Meetings.

The teleprinters which have been installed at race courses in the vicinity of London have proved fully capable of dealing with the volume of work during the peak period and appear to have practically eliminated the necessity to resort to Wheatstone working.

Presentation to Mr. H. C. Stone.

On March 31st, Mr. H. C. Stone, Executive Engineer of the City External Section, retired from the Engineering Department after a long service, during which he had earned the esteem of all those who came into contact with him. The exceptionally large gathering to witness the presentation must have been very gratifying to Mr. Stone, as it furnished evidence that although he set a high standard of efficiency, and sought by every means to obtain this standard, he had been able to carry his staff with him. Mr. Stone will be missed in many ways, and not least on account of the excellent relations he established with the officials of the local authorities and of the various undertakings which carried out underground operations or building construction works in the City of London. It is not possible to express in monetary terms the value to the Department of the ability to co-operate in this way and thus obtain, in a few minutes of friendly discussion, facilities which might otherwise take many months to obtain by correspondence, and, in some cases, only after legal proceedings.

Several of those present spoke of Mr. Stone's calmness in periods of emergency, coupled with energy and initiative, and one expressed it in the following verses, which although not the highest type of poetry, might well be learnt and applied by younger men :—

" Somebody said that it couldn't be done,
But he with a smile replied,
That maybe it couldn't but he was one,
Who wouldn't say so till he'd tried.

So he buckled right in with a trace of a grin,
On his face. If he worried he hid it,
And he began to sing as he tackled the thing,
That couldn't be done, and he did it."

Mr. Gomersall made the presentation, and spoke in very high terms of the services rendered by Mr. Stone to the Department, and of the high regard in which he was held by the higher officials as well as those who worked under him.

Staff Changes.

Mr. Harvey Smith has been transferred to the City External Section, and his position in charge of the West External Section has been taken by Mr. W. F. Boryer, formerly Assistant Engineer in that Section.

A Novel Reconstruction Job.

W. A. Sullivan.

Building reconstruction work of an uncommon character has recently been carried out at one of the Exchanges in the London Engineering District.

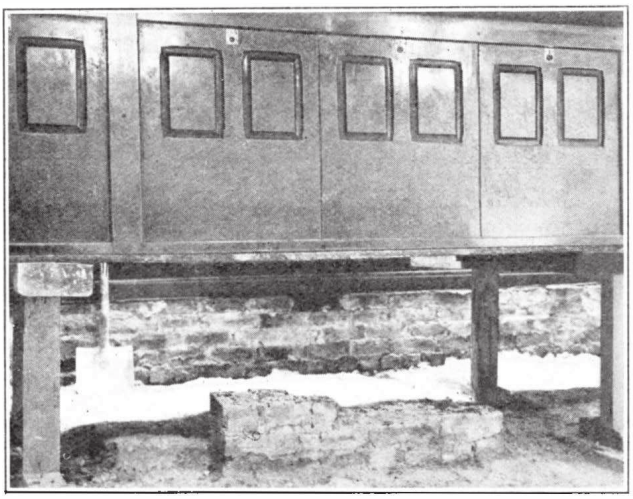


Fig. 1.

Upon the transfer of the subscribers from Primrose Manual Exchange to the Automatic Exchange, it was decided that the former equipment, which is situated in what was formerly a church, should be reconditioned and re-opened at a later date as Cunningham Manual Exchange. The first step in this direction was an inspection of the flooring and joists of the switchroom by the Office of Works, owing to dampness having been encountered in parts of the floor, when it was found that dry rot was very prevalent and it was decided that the whole of the joists and floor boards should be renewed.

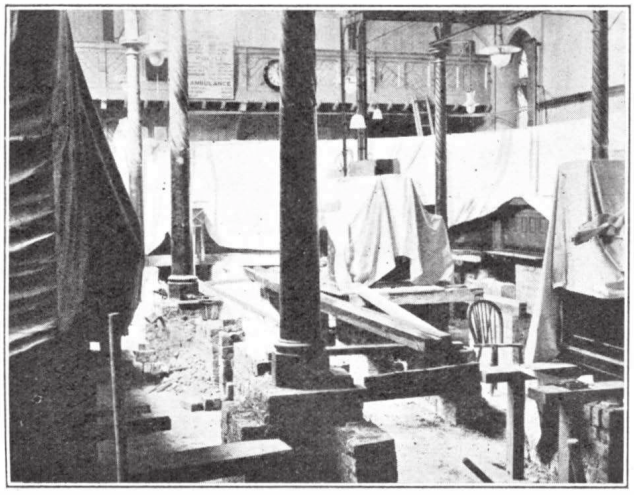


Fig. 2.

During the process of the work the switchboards were, in the case of the " B " Boards, temporarily supported by quartering as shown in Fig. 1, while the new woodwork was placed in position. From the experience gained, it was then decided to abandon this method, as far as the " A " Boards were concerned, and they were supported on jacks, a section at a time, while the old joists and floor boards were removed, new joists treated with solignum, and floor boards placed in position.

Fig. 2 shows a general view of the switchroom with the brick piers for supporting joists in the process of renewal, the " B " Board being on the left, Information Desk in the centre, and the " A " Board in the background.

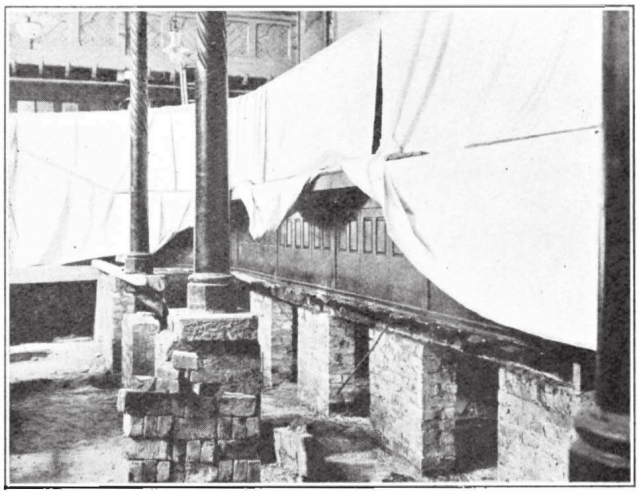


Fig. 3.

Fig. 3 shows the " A " Boards with the old brick piers, cut away portions of joists and floor boards, prior to the switchboard being raised on jacks.

S. LANCS. DISTRICT.

Manchester Automatic Scheme.

Progress on the Manchester Automatic Scheme proceeds apace. Installation work on the new Director Automatic Exchanges, namely, Ardwick, Collyhurst, and Moss Side, is now completed, together with their associated Auto-Manual Boards, centralised at Telephone House,

Chapel Street, Salford. The Exchanges were brought into service at 2 p.m. on June 7th, 1930. The transfer is of some interest, as the Exchanges are the first Director Exchanges to be brought into operation in the provinces, and are the first step in the scheme for the conversion of Manchester Auto area to Director working. Only a portion of the complete Auto-Manual Board was brought into service at first, as indicated hereunder:—

33 "A" positions.
10 Enquiry positions.
10 "4-digit" key sender positions (for dealing with traffic from City and Central Manual Exchanges to the Automatic Exchanges).
1 Supervisor's desk.

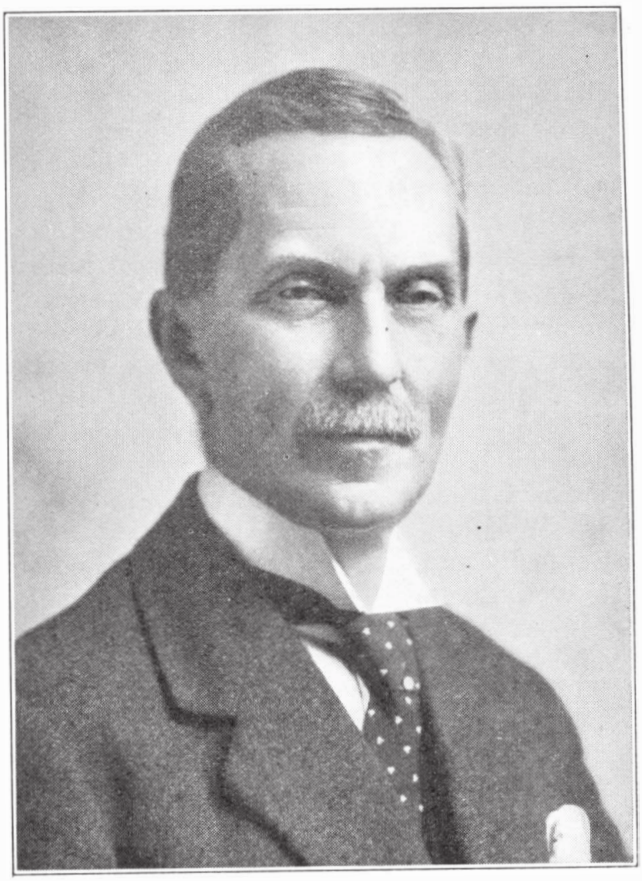
An interesting innovation in connection with the Auto-Manual Board is that this is the first time the system of straightforward junction working has been introduced in a Director area.

Ardwick Exchange is of the Siemens type, Collyhurst the S.T. & C. type, and Moss Side is of the G.E.C. type. The first opened with approximately 1,700 lines, the second 1,000 lines, and the last 1,400 lines. In addition to the installation of the equipments previously referred to, C.C.I. equipments have been installed at the Manchester City and Central Exchanges for the receipt of calls direct from the Automatic Exchanges. Other Manual Exchanges in the Auto area will not be equipped with C.C.I. positions during the initial period of Automatic working, *i.e.*, until 1931. Automatic subscribers requiring these Exchanges will obtain connections *via* the Automatic Manual Board.

In order to prepare the subscribers for the transfer from Manual to Automatic working an automatic demonstration set has been installed at H.P.O., Manchester, and has done good work in demonstrating to subscribers how the new system works.

Retirement of Mr. W. J. Medlyn, O.B.E., M.I.E.E.

Mr. W. J. Medlyn, M.I.E.E., has had a long and distinguished career in the Post Office Engineering Department, and his retirement leaves a gap which will indeed be difficult to fill.



Mr. W. J. Medlyn, O.B.E., M.I.E.E.

Born in a remote part of West Cornwall, he first entered the Service as a "Learner" at Falmouth. After a short interlude with the Direct Spanish Telegraph Company he rejoined the Post Office at Cardiff. His theoretical electrical training was obtained at the University College of South Wales and Monmouthshire and in 1891 his engineering experience commenced under the late Sir John Gavey. In due course Mr. Medlyn became Sectional Engineer at Leeds, and it was during this period that he devised the superposing plan which did so much to extend the telephone service to remote villages. In the late nineties Mr. Medlyn devised a plan which did for telephone trunk signalling what the Secondary Cell system of working had done for telegraphs, thereby replacing the hordes of primary cells by a power installation.

In 1901 Mr. Medlyn was called to London, and there ensued a period of strenuous effort during which he redesigned the Post Office trunk switchboards and the signalling system.

This new system was applied to the London Trunk Exchange, opened in 1904, and was followed by the installation of similar equipment at all the more important provincial centres, such as Manchester, Liverpool, Birmingham, etc. These equipments were manufactured and installed by The British Insulated Cables, Ltd., of Prescot and Helsby, and they constituted the beginnings of the extensive telephone works which are now carried on by The Automatic Telephone Manufacturing Co., at Liverpool. The designs embodied many apparatus devices which facilitated the handling of long distance traffic and included the invention of a three-minute time check to assist the operating staff to deal with the timing of trunk calls.

Mr. Medlyn's administrative abilities were very speedily recognised. His really deep knowledge of accountancy, his ever-living interest in costing, and his flair for statistics, distinguished him from his fellows in the days when such sordid subjects were anything but popular. And he has remained in the Service long enough to see the basic principles which he has preached in season, and out of season, definitely established as an essential part of the scheme of things. Whilst always aiming at the highest efficiency, he has consistently recognised that the cost of absolute perfection may be prohibitive, and therefore uncommercial. He has certainly instilled these ideas in the minds of his staff—a staff which has ever been happy in his leadership.

In 1908 Mr. Medlyn came to Manchester as Assistant Superintending Engineer, and in 1913 became Superintending Engineer of the South Lancashire District. Practically the whole of the arrangements in connection with the transfer of the late National Telephone Company's plant to the State and the organisation of the staff fell upon his shoulders, and the success of this work was no doubt due to his native grit, bred in a bit of old England, where the ideal of duty has never been dimmed by questions about the magnitude of the resulting rewards. But, be this as it may, there can be no doubt that the burden thrown on to Mr. Medlyn was indeed onerous; the work was, however, so efficiently and so thoroughly executed that the prestige of the South Lancashire District rose ever higher and higher. The number of telephone stations increased from 67,856 to its present figure of close on 170,000, but even more significant was the continual fall in the cost of every item of maintenance and construction work. This latter result was no doubt in large measure due to the statistical methods which Mr. Medlyn devised, and used so effectively, to raise the efficiency of the multitudinous operations which represent the output of the South Lancashire District.

The subject of this sketch, if he were asked for the form in which the memory of his life's work should be perpetuated, might well reply as Sir Christopher Wren replied, when asked the same question, in the single word " Circumspice! " And, when we do look around us we observe the entire disappearance of beds of open wires and roof-standards in the cities and towns of South Lancashire. The network of underground cables which connects all the Lancashire towns and villages disposed around Manchester is unequalled in magnitude and comprehensiveness in other parts of the world. Modern exchanges have replaced those of earlier days and the new era of automatic telephony in the Manchester area will commence on June 7th—just a week after Mr. Medlyn's retirement.

Perhaps one of the most valuable features of Mr. Medlyn's work has been the close personal attention which he has given to the establishment of cordial relations with local authorities. This has been accomplished by unremitting vigilance in promptly seeking to satisfy local requirements. The manifestation of a sincere desire to understand another's point of view, coupled with an ambition to help, and if possible to find an acceptable solution to every difficulty, has naturally reacted in producing a friendly atmosphere. This is particularly noticeable in the attitude of the various Chambers of Commerce, and it is difficult indeed to over-estimate the value of this phase of Mr. Medlyn's work.

After the conclusion of the Agenda of the last meeting of the Whitley Committee at which Mr. Medlyn presided, the Chairman of the Staff Side expressed his appreciation of the sympathetic consideration and careful thought bestowed upon every question raised on the Committee. After similar remarks by Mr. C. H. P. Kent and Mr. Hepplestone, Mr. Whittaker presented a little token of esteem and regard to Mr. Medlyn, from present and former Staff Side members of the

Committee. This little ceremony was indeed a striking testimony to the ability with which the principles of Whitleyism had been applied in the South Lancashire District. The main feature has certainly been Mr. Medlyn's keen and obvious desire to secure absolute justice and the Staff Side members fully appreciate that always and in every possible circumstance they have had a square deal. What more can one desire?

So much for the purely official work. There are, however, yet other important directions in which he has served his day and generation. As Chairman of the South Lancashire Centre of the Institution of Post Office Electrical Engineers he has each year delivered a Presidential address of very great value in crystallising the developments of the past year.

He has, for many years, been a member of the Manchester Geographical Society, and has for some time served on the Council of that Society. He has taken an active part in promoting the interests of the Institution of Electrical Engineers, and became Chairman of the North Western Centre during the 1926-27 Session. To him we owe the inauguration of the joint meetings between the Institution of Electrical Engineers and the Institution of Post Office Electrical Engineers. In fact, it is only just here to observe that no opportunity of advancing the prestige of his Department, and of his Officers, has ever been neglected, no matter what the pressure of his ordinary duties may have been.

The final note must necessarily deal with the man rather than the Official. It has been said that the Official oft decays the man, but it has not been so in this case, at least. Mr. Medlyn has won the kindly regard of everyone. At heart personal advertisement is distasteful to him, and consequently the performance of public duties involves a comparatively severe strain. Nevertheless, whenever the circumstances have imposed this necessity, he has invariably performed the required ceremony with distinction and efficiency. The result of these efforts has been that to-day it can justly be said that Mr. Medlyn makes speeches which may be described as admirable cameos; depicting precisely what he wishes to convey in a direct and attractive manner.

So far as his relations with his Staff are concerned, it is only in accordance with truth to say that he demanded from everyone the best that was in him, just as he himself was utterly unsparing in his own efforts. It may be that the discipline in the South Lancashire District is stricter and sterner than in any other, but it has this advantage, that deviation from the straight and narrow path of duty is checked long before the offender can form habits which will seriously affect his future career. On the other hand, every man, from top to bottom, could rely on careful and sympathetic consideration, with absolute justice, but inspired by an earnest desire to help the individual and thus to advance the best interests of the Service he loves so well, and the well-being of the man concerned.

The writer of this little memoir has had the honour to serve Mr. Medlyn as his Assistant for ten years, and the passage of time has only increased his appreciation of a remarkable brain directed by a kindly heart.

T.E.H.

Presentation to Mr. Medlyn.

There was a remarkable gathering at the Manchester Limited Restaurant on the 31st May, the last day of Mr. Medlyn's service. The guests were received by the Chairman (Mr. T. E. Herbert), Mr. Medlyn and Sir Thomas Purves. A simple little meal was then admirably served.

After this, Mr. Medlyn performed his last official duty by investing Mr. W. H. Martin, S.W.2, with the Imperial Service Medal.

A musical interlude followed and then speeches in honour of the guest of the evening were made by Col. Sir T. F. Purves, President, I.E.E., Engineer-in-Chief to the Post Office, Mr. J. W. Atkinson, Superintending Engineer, N.E. District, Mr. H. Downes, Mr. J. G. Maddan (Postmaster Surveyor of Manchester), Messrs. T. McLeod, F. N. Harrop, C. H. Smith (General Secretary of the Post Office Engineering Union), G. H. A. Wildgoose, H. Broadhead, H. Hepplestone and Sir William Noble. The speeches were, without exception, brilliant and the large audience followed them with eager interest. The duration of the speeches was strictly limited and was controlled by the lighting of green, orange, and red lamps; it was amusing to observe the Chairman timing each speaker with an official

stop watch. He was quite impartial and at the end of 2½ minutes the speaker got the orange light, followed half a minute later by a red light. Sir Thomas and Sir William, however, both outwitted the Chairman by signalling their own conclusion lights.

The presentation, which comprised a portable wireless set, a gramophone, camera and a handbag for Mrs. Medlyn, was then made by the Chairman (Mr. T. E. Herbert) in a few brief but well-chosen sentences—incidentally, he remarked that the earlier speeches were not merely a case of *de pensionis nil nisi bonum*. Anyone who denied Mr. Medlyn's high qualities was either a follower of Ananias or a direct lineal descendant of Balaam's Ass.

Mr. Medlyn in reply expressed his appreciation of the magnificent tribute which had been paid to him not only by the personal gifts, but even more by the character of the gathering. It would be a happy memory which would remain with him to the closing hour of his existence.

The company numbered some four hundred and the gathering may well be described as unique. Not merely in point of size, but in the warmth of the atmosphere and in the sincere cordiality of the proceedings. Many messages of goodwill were received from those unable to be present and if one of them may be selected for special remark it is the message to Mr. C. H. Smith from the President and Executive Committee of the P.O.E.U. charging him to convey their good wishes to Mr. Medlyn.

The speeches were all perfectly audible in all parts of the large banqueting hall and for this the Chairman expressed his thanks to Mr. Storey, of the Standard Telephones & Cables, for the installation of a microphone and loud speakers.

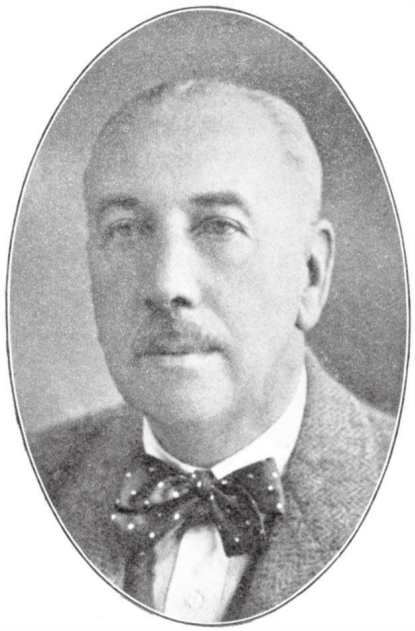
An unforgettable evening concluded with a vote of thanks to the Chairman, despite his frenzied operation of the red light!

W.C.

Honours.

The Birthday Honours List contains the name of William John Medlyn as an Officer of the Order of the British Empire. We congratulate Mr. Medlyn very cordially and would add that this honour has never been more worthily bestowed.

Mr. T. E. Herbert, M.I.E.E.,
Superintending Engineer, South Lancs.



Mr. T. E. Herbert, M.I.E.E.

Mr. T. E. Herbert was appointed as Superintending Engineer of the South Lancashire District on the 1st June. He is at present Chairman of the North Western Centre of the Institution of Electrical Engineers. He has for the past ten years occupied the position of Assistant Superintending Engineer to Mr. W. J. Medlyn, O.B.E., M.I.E.E., who has just retired.

In his younger days, Mr. Herbert was well-known as a lecturer on Telegraphy and Telephony and he is the author of various works on these subjects. The 5th edition of his "Telegraphy" was published recently and has met with a most favourable reception.

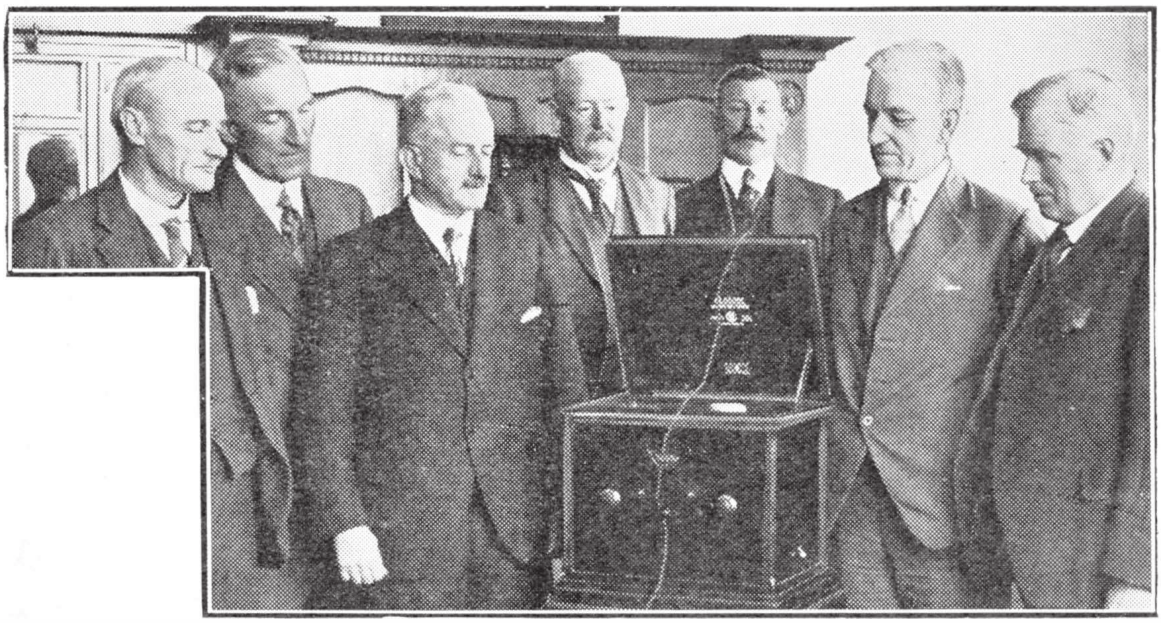
SCOTLAND WEST DISTRICT.

A distinguished statesman referring the other day to the Government Telephone Service, said they had men on their staff who might be said to have followed the telephone from its cradle, and were still ahead with all the latest marvels of wireless telephony. He might well have been describing the life of Mr. Robert Aitken, M.I.E.E., Superintending Engineer, Scotland West District, who has just retired from the Service after a distinguished career.

In connection with his severance of office, Mr. Aitken, at a large and representative gathering of the staff, presided over by Mr. R. Cunningham, was presented with a handsome 3-valve Madrigal Wireless Set and Loud Speaker in recognition of his long service and also as an appreciation of the staff's esteem and affection. The presentation was made by Major John Cameron, O.B.E., M.I.E.E., Assistant Superintending Engineer.

and Sir John Gavey in connection with the valuation of the trunk telephone circuits prior to their transference to the Government.

Mr. Aitken was also responsible for the preparation of all the early traffic and underground schemes carried out by the National Telephone Company. When the Post Office entered into an agreement to rent the underground plant to the company in London, all the arrangements on the Company's side were made by him. Prior



PRESENTATION TO MR. R. AITKEN.

A. Scott. G. Morrison. Major Cameron. R. Cunningham. J. C. Witherby. R. Aitken. G. W. Crawford.

Looking back at the milestones of life Mr. Aitken has passed—and it may be recalled that he has given many young men heartening to make some of their milestones in times of stress—it can be said that this gentleman from the "Capital of Golfland" has helped to build up and extend the British telephone system.

He has links with the old service, and many interesting recollections of these far off days when a telephone in some country villages was looked upon as something just a little uncanny. He joined in 1891 the National Telephone Company and two years later he was transferred to its engineering department.

He was what is known as "a young man o' pairts," and by 1896 he was chosen to go on a tour of the country with Mr. Dane Sinclair, the Manager of the National Telephone Company, to the transfer of the National Telephone Company's local lines to the Post Office in 1912, he was in charge of the Company's headquarters staff in London engaged in the inventory and valuation of the plant.

When the transference to the Government took place Mr. Aitken joined the staff of the Post Office Engineer-in-Chief in London as Assistant Staff Engineer and was promoted in 1926 Superintending Engineer to the West District of Scotland.

In Mr. Aitken's early days in London he was an enthusiastic Rugby Football player and also a great pedestrian. His hobbies at the present time are Wireless and Walking — the two "W's." While a non-smoker, he has been known as a cautious Fifer to take a little whisky with his haggis, but never known to drown it.

In Caledonian circles in London and at Clan gatherings and concerts, Mr. Aitken was well-known, but, unless to his intimates, he was regarded as a typical Scot who heard everything but said very little.

Mr. Aitken will be missed in Glasgow, but he has the best wishes of many in his retirement. It is not known if he ever intends to go back to St. Andrews, his native town, in order to qualify for some of the big prizes in golf, but in the meantime he will continue to reside in Helensburgh.

MR. CHARLES WHILLIS, M.I.E.E.,

Superintending Engineer, Scotland West.

MR. CHARLES WHILLIS, M.I.E.E.

MR. WHILLIS entered the Post Office service in 1889 as a telegraphist at Newcastle-on-Tyne, but like many more Tynesiders he was not content to remain so and in 1896 he was transferred to the Engineering Department as Junior Clerk at Newcastle. He was made Sub-Engineer in 1899 and was engaged in the installation and maintenance of the old NEN system under Mr. A. W. Heaviside. Three years later Mr. Whillis came to London as 2nd Class Engineer and served in the District and in the Telephone Section at headquarters for seven years. He then returned to his old District as Executive Engineer, first at Carlisle and then in NT South and the Technical Section. He was promoted Assistant Staff Engineer in March, 1926, and was attached to the Construction Section for two years and to the Lines Section for the last two years before going to Glasgow. Mr. Whillis served on the Comprehensive Railway Agreement Committee and on the E.-in-C's Office Staff Reorganisation Committee with much acceptance. In his earlier days Mr. Whillis was a keen technical student and was C. and G. Medallist in both Honours Telegraphy and Telephony.

SOUTH WALES DISTRICT.

RETIREMENT OF MR. JOHN BLEADEN RYALL.

MR. JOHN BLEADEN RYALL.

The retirement in March of Mr. Ryall, Sectional Engineer, Gloucester, has left a gap in the now very small band of men still in the service who were associated with the development of the telephone in this country in the early eighties. Mr. Ryall entered the service of the old United Telephone Company as far back as 1883 and for thirty years he was stationed in London, his experience during that period covering practically all sides of both engineering and traffic work. In 1914 he was promoted Executive Engineer and was given charge of one of the Cardiff Sections. In 1919, on the combination of the two Cardiff Sections, Mr. Ryall went to Gloucester in charge of that Section. During

his regime of eleven years in Gloucester, there has been a very large expansion of the telephone system in the Section, 40 new exchanges having been opened in rural areas alone, while the conversion of the Gloucester and Cheltenham exchanges to Automatic working a few years ago was carried out to a successful conclusion under Mr. Ryall's direction. The installation of the Gloucester Repeater Station was another important piece of work.

Enthusiastic and keen about his work, Mr. Ryall was himself a hard worker and by precept and example encouraged all members of his staff to follow his lead in that respect. He was held in high esteem by all ranks, who appreciated the care Mr. Ryall took to be scrupulously fair to everyone, while his generous and sympathetic nature was always responsive to a case in which a man was in any kind of trouble. In the exercise of his official duties, Mr. Ryall added to his thorough knowledge and long experience a habit of applying what may perhaps be described as a common-sense test to the various problems with which he had to deal. To this quality of mind and to his genial disposition, much of the considerable success which Mr. Ryall achieved in the Gloucester Section is undoubtedly due. He is widely-known and popular in Gloucester, where he was a member of the Rotary Club. It is understood that he intends to continue living in Gloucester, for the immediate future at any rate. Mr. Ryall is an enthusiastic motorist and, now that he has plenty of time at his disposal, he will no doubt spend part of it in seeing the country more thoroughly than he has had an opportunity of doing before.

On 27th May Mr. Ryall was presented by Mr. Terras with a gold watch subscribed for by the members of the Gloucester Section Staff and by his colleagues in other parts of the South Wales Engineering District and on the District Manager's and Postmasters' staffs. All his old friends hope he may be long spared to enjoy his years of retirement.

NORTH WALES DISTRICT.

Mr. George William Billingham.

On the 18th January last, Mr. G. W. Billingham retired from the position of Executive Engineer of the Birmingham External Section, having completed 46 years in the Department's service.

Mr. G. W. Billingham.

Mr. Billingham entered the Telegraph Service in January, 1884, and was appointed S.C. & T. in August of that year at Birmingham.

Being studiously inclined, he applied himself to technical studies, and was transferred to the Superintending Engineer's Office of the then South Midland District at Birmingham, in July, 1897, as Junior Clerk. The engineering side of the service presenting the greater appeal, he became a Sub-Engineer in August of the following year, taking up duty in the Chester Section. Four years later he was promoted to Second Class Engineer at Bolton, where he remained until 1908. In that year he was attached to the Survey Staff of the Engineer-in-Chief's office, spending three years on valuation work preparatory to the transfer of the National Telephone Company's plant to Post Office control.

He was promoted to the rank of Executive Engineer in December, 1911, and was posted to the Bangor Section. He was transferred to Chester in 1915, and in August, 1917, took over control of the Birmingham External Section, where he spent a strenuous time for nearly thirteen years.

At the time of the transfer the Birmingham

and Black Country areas were left with a very inadequate underground plant system, and the restrictions on expenditure imposed during the War period rendered the position worse. For many years the Section Staff were busily engaged in laying large quantities of duct and cable in the endeavour to overtake arrears, and in preparation for the change-over to automatic working. Mr. Billingham only saw the beginning of the change-over, but the work of his successor in completing the extensive programme will be greatly facilitated by the preparatory work carried out under his control.

As an administrator, Mr. Billingham inspired his staff with confidence and gained their loyalty and respect. He was ever willing to take up the cudgels in their interests, and was always ready to assist any member of the staff, to whom he was always accessible for consultation. His close relationship with the staff was also extended to their recreation; he was a keen participator in numerous billiard handicaps, and devoted much time to the Cricket Club of which he was President. In the latter he was ably supported bv Mrs. Billingham.

At a Smoking Concert held recently, which was attended by about 200 members of the Engineering, Traffic and Telegraph Staff and other friends, Mr. Billingham was presented with a quantity of pewter ware, a travelling case and a loud speaker, and Mrs. Billingham was also asked to accept a valuable gold bangle. The presentation was made by Mr. R. A. Weaver, M.I.E.E., the Superintending Engineer of the District, who, speaking in high terms of Mr. Billingham's ability and personal attributes, expressed the view that his outstanding characteristic was his absolute dependability on all occasions. He was supported by Major H. Brown, O.B.E., R.E., Asst. Engineer-in-Chief, Mr. F. H. Horner and Mr. G. Richardson, old friends of many years' standing, all of whom spoke in glowing terms of their colleague and expressed their good wishes for his future. Many members of the staff voiced their appreciation of their late chief, and Mr. R. P. Collins, in a humorous speech, asked his acceptance of a framed photograph of the Cricket Team.

An excellent musical programme was arranged, the whole of the items being provided by members of the Department's Staff, and a thoroughly enjoyable evening was closed by the singing of Auld Lang Syne.

SOUTH EASTERN DISTRICT.

Automatic Telephones.—The transfer of the Maidstone Area to Automatic working was very successfully carried out on the 26th April, 1930.

The work in connection with the transfer of the Folkestone Area is progressing satisfactorily, with April, 1931, as the prospective date for transfer. The area includes the following Exchanges: — Folkestone, Cheriton, Hythe, Lyminge and Sandgate.

Main Cables.—The following main cables are in course of construction:—

Anglo-Belgian Cable. 7 Quad continuously loaded, Canterbury *via* Dumpton Gap to La Panne.

Anglo-French Cable. 104 pr/20 P.C. Quad cable with 56 prs. pot loaded Canterbury to Seabrook, 7 Quad continuously loaded cable Seabrook to Le Portel.

Brighton-Hastings. 38 pr/70 P.C. Quad cable. Hastings to Bexhill Section.

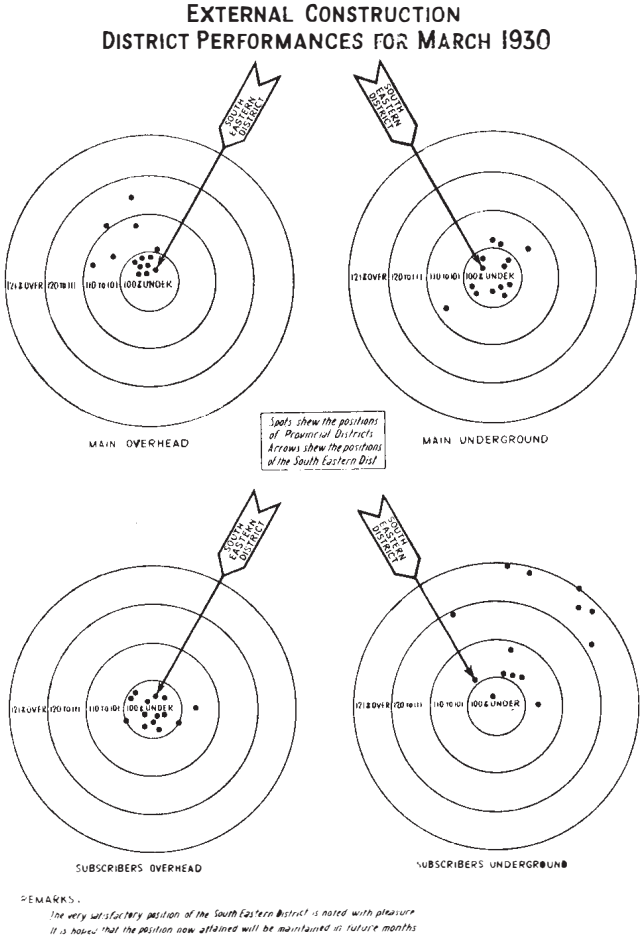
Dover-Folkestone. 38 pr/40 P.C. Quad cable.

Polegate-Hailsham. 38 pr/70 P.C. Quad cable, Polegate to Horeham Road. 28/70 P.C. Quad, Horeham Road to Hailsham.

Pitts Head—Haywards Heath. 28 pr/70 P.C. Quad cable.

External Construction Costs.—The problem of getting external work performed at the rates considered by the Engineer-in-Chief to be reasonable has exercised the minds of all supervising officers in the District since the Performance Rating Scheme was initiated. At the outset arrangements were made to circulate to foremen in each Inspector's area a list of their own and their colleagues' performances. This, though in some respects effective, led to a certain amount of discouragement on the part of foremen whose high percentages were due to causes beyond their control. A way was sought to maintain the men's interest in the matter without confusing them with references to graphs or schedules. The treatment of the Section as a team for comparison with other Sections in the

District and the District as a whole for comparison with other Districts was thought to be the fairest method and the one most likely to attain the desired result. By treating the Sections as teams the difficulty arising from inequalities in the grade of work is overcome. So far as the means for presenting the results to the men are concerned it was thought that the most easily understood and the most striking arrangement would be to record the results in target form with arrows to indicate the position of each team as shown in the Fig.


EXTERNAL CONSTRUCTION
DISTRICT PERFORMANCES FOR MARCH 1930
SOUTH EASTERN DISTRICT
121 & OVER
120 TO 111
110 TO 101
100 & UNDER
MAIN OVERHEAD
Spots shew the positions of Provincial Districts
Arrows shew the positions of the South Eastern Dist
MAIN UNDERGROUND
SUBSCRIBERS OVERHEAD
SUBSCRIBERS UNDERGROUND
REMARKS.
The very satisfactory position of the South Eastern District is noted with pleasure
It is hoped that the position now attained will be maintained in future months

Arrows show the position of the S.E. District on the work targets.

There is ample evidence to prove that the men are keenly interested in securing a satisfactory position for their Section on the diagrams issued monthly, and since the first issue of targets the performance ratings have materially improved throughout the District.

SOUTH MIDLAND DISTRICT.

The outstanding feature of the opening months of this year was the great wind storm of the 12th January from a W.S.W. direction. Its effects on the overhead plant in the South Midland District were worse than any experienced in late years. Throughout the area routes were brought down by falling trees and every main overhead line was affected. In many cases successive breaks occurred for long stretches, miles in extent. The damage was spread over the whole of the District and the work of repair presented a difficult problem of organization.

Blocked roads and the continuance of the stormy conditions rendered the work of preliminary clearing very difficult, but by the end of a week communication was established on most of the main line routes. Special attention was given to the lines carrying B.B.C. circuits, so as to ensure that the arrangements for broadcasting His Majesty's speech at the Naval Conference on the 21st January should be satisfactory. All circuits of the Leafield W.T.S. were broken down, but by the evening of the 15th service was given on one line and restoration of the remaining circuits followed quickly.

The permanent repairs have thrown a heavy burden on the District. The extent of the damage called for the best efforts of the Staff and this was given without stint by all ranks.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

THE Annual General Meeting of the Institution was held at the Institution of Electrical Engineers, London, on Tuesday, May 13th, 1930. The Chair was taken at 5 p.m. by the President, Colonel Sir Thomas Fortune Purves, M.I.E.E.

The following Agenda was then carried through:—

Presentation of Annual Report of Council.
Presentation of Statement of Accounts for Year 1929-30.
Resolution that Annual Report and Statement of Accounts be accepted.
Vote of thanks to retiring Members of Council.
Presentation by the President of the Medals for Session 1928-29.

AWARD OF MEDALS FOR SESSION 1928-29.

Senior Silver Medal to Mr. W. G. Radley, B.Sc. (Hons.), A.M.I.E.E., for his Paper No. 121 on "X-rays and the Structure of some Engineering Materials."

Senior Bronze Medal to Mr. A. J. Aldridge, A.C.G.I., A.M.I.E.E., for his Paper No. 124 on "The Measurement of Sound and its Application to Telephony."

PRINTED PAPERS.

The following is a list of the printed papers issued to the Membership during the year:—

No. 121. "X-rays and the Structure of some Engineering Materials," W. G. Radley, B.Sc.(Hons.), A.M.I.E.E.
No. 122. "The Measurements of Relay Times," R. W. Palmer, A.M.I.E.E.
No. 123. "Modern Electrical Illumination," J. J. Edwards, B.Sc.(Eng.), A.C.G.I., D.I.C.
No. 124. "The Measurement of Sound and its Application to Telephony," A. J. Aldridge, A.C.G.I., A.M.I.E.E.

ESSAY COMPETITION.

The prize winners in the recent Essay Competition, arranged in order of merit, are as follows:—

1. W. A. Stripp, Testing Branch, Birmingham. "Phototelegraphy."
2. W. H. B. Cooper, Repeater Station, Marlborough. "The Thermionic Valve as a Speech Frequency Amplifier."
3. R. J. S. Tuddenham, Radio Section, E.-in-C.O. "The Thermionic Valve."
4. A. F. Street, Bedford. "The Nature of Electricity."
5. H. W. Jarvis, Brighton. "The Siemens No. 16 Key Sending "B" Position."

The Council has decided to award Certificates of Merit to the following three competitors who were next in order of merit:—

6. W. H. Maddison, London District. "The Physics of the Thermionic Valve."
7. R. N. Renton, Circuit Laboratory, E.-in-C.O. "Interconnection of Automatic and Manual Exchanges."
8. T. A. Marks, Petersfield, Hants. "Notes on Exchange Construction by Contractors."

The number of essays submitted was 42 and although the number is somewhat smaller than in previous years the Judges reported that the average standard of the essays submitted is high.

COUNCIL FOR THE YEAR 1930-31.

The constitution of the Council for the year 1930-31 will be as follows:—

Chairman—Mr. E. H. Shaughnessy.
Honorary Treasurer—Mr. C. J. Mercer.
Representing Staff of the Engineer-in-Chief's Office—
Mr. B. O. Anson and Mr. C. W. Brown.
,, Executive Engineers—
London: Mr. W. C. Burbridge.
Provinces: Capt. N. F. Cave-Browne-Cave.
,, Asst. & Second Class Engineers—
London: Mr. J. Prescott.
Provinces: Mr. G. Bailey.
,, Chief Inspectors—
London: Mr. A. Miller.
Provinces: Mr. W. Weightman.

Representing Clerical Staff—
London: Mr. E. H. M. Slattery.
Provinces: Mr. J. Mawson and Mr. A. C. Smith.
,, Inspectors—
London: Mr. N. Layton.
Provinces: Mr. R. P. Collins.
,, Draughtsmen—
London and Provinces: Mr. R. J. Stewart.

Secretary—Mr. P. G. Hay.

LONDON CENTRE.

The Annual Meeting of the Institution held on the 13th May was followed by a meeting of the London Centre, at which a paper by Messrs. J. M. Owen and J. A. S. Martin, on "Composited Telephone and Telegraph Working," was read before a large audience. Mr. Owen read the paper and Mr. Martin replied to the discussion, which was taken part in by a number of well-known telegraph and transmission experts. The paper was illustrated by lantern slides.

LOCAL CENTRE NOTES.

SOUTH LANCS. CENTRE.

The Sixth Meeting of the Session was held on Monday, March 10th, 1930, when a paper on "Composite Telegraph and Telephone Working" was presented by Messrs. J. M. Owen, A.M.I.E.E., and J. A. S. Martin, of the Engineer-in-Chief's Research Section. The paper proved to be of considerable interest and a very useful discussion resulted.

The seventh and final meeting of the Session was held on Monday, April 7th, 1930, when a paper on "The Manchester Repeater Station" was read by Mr. S. Jackson. The paper dealt very fully with the lay-out of the Station, the circuit and cabling arrangements for 2-wire, 4-wire, and cord circuit repeaters, and the routine work necessary in the lining up and bringing the repeater units into use. On account of its length the paper had to be somewhat abbreviated, but with the aid of a series of lantern slides the author was able to present adequately the main features of the paper. A good discussion followed.

Before the meeting closed a vote of thanks was passed to Mr. W. J. Medlyn for his services as Chairman of the South Lancashire Centre over a long and memorable period. Several speakers paid tribute to the excellent manner in which he had undertaken the work and emphasised how the prestige of the Institution had been raised largely through his unsparing efforts.

NORTH WESTERN CENTRE.

The closing meeting of the 1929-30 Session was held in the Lancaster Road Institute, Preston, on the 17th March, 1930, when a paper entitled "Cells" was read by Mr. T. Woodhouse, A.M.I.E.E.

The Chairman of the Centre (Mr. J. M. Shackleton) presided.

Mr. Woodhouse first dealt with Primary Cells, their construction and maintenance. He then proceeded to deal at length with the subject of Secondary Cells and covered construction, installation, charging and maintenance. The lecture was illustrated by lantern slides and was followed by a lengthy discussion.

D.B.

SESSION 1930-31.

LOCAL ORGANIZATION.

Chairman—Mr. J. M. Shackleton, M.I.E.E.

Vice-Chairman—Mr. S. Upton, M.I.E.E.

Committee—Messrs. H. Butterworth, A. S. Carr, B.A., A.M.I.E.E., E. Hopper, A.M.I.E.E., W. H. Lane, W. G. Morris and H. F. Perry.

Librarian—Mr. H. Howarth.

Secretary—Mr. D. Barratt, Office of the Superintending Engineer, G.P.O., Cross Street, Preston.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

Officers of Colonial and Foreign Telegraph Administrations who are engaged in Electrical Engineering Works may be admitted as Colonial and Foreign Corresponding Members respectively, after application.

Subscription payable annually in advance on 1st April in each year:

Colonial Members	...	...	£1 0 0
Foreign ,,	...	...	£1 10 0

These sums include Annual Subscription to the Journal of P.O. Electrical Engineers and the supply of all Professional Papers issued during the period covered by subscription.

Forms of application for Colonial and Foreign Membership can be obtained on application to

The Secretary,
Institution of P.O.E. Engineers,
G.P.O. (Alder House), E.C.1,

or the undermentioned gentlemen who have kindly agreed to act as representatives of the Institution in their respective countries:—

R. Badenach, Esq., B.Sc. (Melb.),
Chief Engineer's Office,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2,
Australia.

H. C. Brent, Esq.,
District Telegraph Engineer's Office,
Wellington, N.Z.

N. N. Banerjee, Esq., A.M.I.E.E. (Ind.),
Divisional Engineer, Telegraphs,
Calcutta West Division,
8, Wellesley Place,
Calcutta,
India.

A. T. Kingston, Esq., M.B.E., A.M.I.E.E.,
Office of the Chief Engineer,
Telegraphs & Telephones,
C.T.O.,
Colombo,
Ceylon.

A. J. Kellaway, Esq.,
Department of Posts and Telegraphs,
P.O. Box 366,
Pietermaritzburg,
South Africa.

F. L. Jephcott, Esq., A.M.I.E.E.,
Chief Engineer's Department,
G.P.O. Box 91,
Salisbury,
South Rhodesia.

BOOK REVIEWS.

"Telegraphy." By T. E. Herbert, M.I.E.E. Fifth Edition. 1199 pp., 750 illustrations. Price 20/- net. Published by Sir Isaac Pitman & Sons, Ltd.

The new edition of this well known text-book covers a wider range than previous editions and embraces the recent machine telegraphy developments in the United Kingdom. The Creed Teleprinters are described at some length with numerous illustrations, and other similar apparatus has not been overlooked.

The Baudot system, including the Mendonça governor, is adequately dealt with in 95 pages.

Voice Frequency telegraph systems, such as the Siemens, Halske, General Electric, S.E.L.T., Western Electric and Wald, are succinctly explained and the achievements of a single channel high speed voice frequency circuit are briefly recorded.

A chapter is devoted to multichannel circuits for double superposed and subaudio methods of working telephones and telegraphs simultaneously, and some of the latest developments are portrayed.

Other new and useful matter is contained in Appendix A, which deals with the recent investigations into the speed of working on loaded and unloaded cables.

The book caters specially for the needs of students, and in this respect fulfils the requirements admirably. As a reference book it can be recommended to all who are interested in the science of telegraphy.

H.K.

"The Theory of Electrical Artificial Lines and Filters." By A. C. Bartlett, B.A. Chapman & Hall, Ltd. 13/6 net.

This book gives a well balanced and comprehensive survey of the theory of lumped networks. The first chapter deals with the mathematics of T and π section artificial lines. The equations are derived from the difference equation which is obtained by an application of Kirchhoff's Law to the r'th section of a ladder network. At the end of this chapter the author gives a few examples showing how the theory can be applied to particular cases. The second chapter deals

with the theory of the general artificial line. The author in order to make his mathematical analysis as general as possible deals with a repeated network which is not electrically symmetrical, and then, by adding the condition for symmetry, he deduces the general artificial line theory as a particular case. The original analysis contained in this chapter will enable the reader to construct and discuss artificial lines of any degree of complexity. The algebra involved, however, except in simple cases, is very heavy. In the third chapter considerable use has been made of the theory of continued fractions in order to discuss the generalised ladder network in which all the elements have arbitrary values. The author then gives a number of practical and interesting examples. The fourth chapter deals with a class of equivalent networks related to artificial lines and discusses the intimate relations that exists between these lines and hyperbolic functions. The fifth chapter discusses the networks related to the uniform transmission line. In the sixth chapter the determination of the constants of a coil loaded line are given as an example of the artificial line theory. The seventh chapter deals briefly with the theory of non-dissipative wave filters and phase correctors and concludes with a description of Boucherot's constant current networks. The next chapter discusses the geometrical aspects of the homographic transformation and its bearing on electrical networks in general. The final chapter gives a general theory of the multistage amplifier.

The book can be thoroughly recommended to readers. The mathematical treatment is brief, clear and original. The diagrams are excellently drawn and reproduced. A very fine work on an important subject.

" The Electric Wiring of Buildings." By F. Charles Raphael, M.I.E.E. 252 pp. Sir Isaac Pitman & Sons, Ltd. Price 10/6 net.

This book is written in a simple and straightforward manner so as to be equally of use to foremen and wiremen, as well as to electrical contractors and others interested in the wiring of buildings for lighting, power, and allied services such as bells, etc.

In addition to dealing with the various systems of wiring, chapters are included dealing with the necessary calculations for the sizes of cables and the provision of adequate illumination.

A statement on page 11 requires alteration in a future edition. This is to the effect that doubling the voltage of supply causes four times the current to pass through the lamp. It is obviously intended to refer to the heating effect of the current, but as written it tends to cause confusion of ideas.

J. McG.

" The Elecric and Magnetic Circuits, Alternating Current and Direct Current." By E. N. Pink, B.Sc., A.M.I.E.E. 122 pp. Sir Isaac Pitman & Sons, Ltd. Price 3/6 net.

This book has been written with the intention of helping the electrical engineering student who, having some knowledge of electricity and magnetism, wishes to study more particularly the subjects of the flow of electricity in simple and complex circuits and also magnetic circuits.

It is based on the theory of electronic flow and being pleasantly written will serve as an introduction to the study of, and calculations in connection with, electrical and magnetic circuits generally, including the use of vectors for A.C. problems.

The book is amply illustrated with diagrams and explanatory examples and is good value for the published price.

J. McG.

" Transmission Networks and Wave Filters." By T. E. Shea, M.S. Messrs. Chapman & Hall. Price 32/- net.

Mr. Shea, a member of the Bell Telephone Laboratories Technical staff, has in this book consolidated the work of a number of men in the fields of transmission networks and wave filters. In particular must be mentioned that of O. J. Zobel, in connection with the theory of wave filters, A. E. Kennelly on transmission theory, and G. A. Campbell on Fourier integral methods.

After an introductory chapter concerned with the functions that networks and filters are called upon to perform, the book is divided into three sections, the first dealing with the principles of transmission networks, the second with electric wave filters themselves and the third with the resolution of transient waves into frequency components by Fourier integral analysis.

The second section is in all probability the one of greatest general interest and develops fully the theory of " constant *k* " and derived " *m* " and double " *m* " sections for low pass, high pass and band filters. From the point of view of design the treatment of the effects of energy dissipation in filters is especially valuable.

The somewhat complicated theory is very well presented throughout the book and, above all, the numerous curves and diagrams are very clear.

J.G.S.

" Installations Téléphoniques." By M. R. Parésy. 6th Edition.

This work deals with the elementary principles of telephony, makes detailed reference to the apparatus employed in subscribers' installations in France, and gives a brief sketch of exchange installations, and the methods of line construction and testing of the French Administration. The book covers a field very similar to that covered by the " Workmen's Pamphlets " of the British Engineering Department and is designed suitably to meet a similar requirement.

For British engineers it is quite a pleasant exercise in Technical French.

The work is published—Bound, 53 francs; Paper covered, 43 francs—by M. Dunod, 92, Rue Buonaparte, Paris, VI.

P.J.R.

" Radio Data Charts." By R. T. Beatty, M.A., B.E., D.Sc. London. Iliffe & Sons, Ltd. Price 4/6 net.

This book is a collection of 76 alignment charts originally published as a series in the *Wireless World* and now revised and amplified for publication in book form.

The charts cover a wide range of subjects from the multiplication of volts and amperes to give watts down to the more intricate computation required for the design of inductances and transformers.

Although a few of the charts such as the volts, amperes and watts abac are of a simple type the great majority will be found to be extremely useful and labour saving. Each chart is accompanied by a page of letterpress giving instructions regarding its use and in the more intricate cases by worked out examples.

No person working on the design of radio apparatus should fail to provide himself with a set of these charts, as by their use calculations which would normally take hours can be carried out in a few minutes. A.J.G.

CURRENT LITERATURE.

The Journal of the Institution of Electrical Engineers, Vol. 68, No. 399, March, 1930.

Alternating-Current Potentiometers. C. V. Drysdale. An historical account of the evolution of the apparatus, with descriptions of the author's and other types of the instrument. Theory and accuracy are discussed and examples given of the application of the instruments for various tests.

The Impedance and Power Losses of 3-Phase Overhead Lines. P. D. Morgan and S. Whitehead. An important item, as far as communication lines are concerned, deals with the impedance of a line conductor and earth return when one phase is accidentally earthed.

Vol. 68, No. 400, April, 1930.

Water Penetration Effects in Lead Sheathed Power Cables. E. A. Beavis.

The Pressures on the Diaphragm of a Condenser Transmitter in a Simple Sound Field. W. West. Free air pressures of a sound wave may be increased at the diaghragm of a microphone in a ratio greater than 2 : 1 at certain frequencies when there is concavity in the face of the microphone. A method of calculating the magnitude of this increase is applied to the Wente type.

Alternating-Current Tests on High Speed Telegraph Cables. E. W. Smith. Paper is concerned with A.C. characteristics of loaded

telegraph cables and their relation to transmission capacity. General principles of transmission are reviewed and performances may be estimated from A.C. characteristics. Methods of testing and apparatus are discussed; departure and arrival curves constructed from theory are compared with records obtained by test. The assumed criteria for satisfactory working expressed in terms of attenuation are verified by transmission tests.

A Method of Measuring the Overall Performance of Radio Receivers. H. A. Thomas.

Address to the Sheffield Sub-Centre. Col. Sir T. F. Purves, President, I.E.E.

Measurements on Long Telephone Lines by the " Open and Closed " Method. A. Rosen. Simplified approximate formulæ are given for calculating attenuation, wave-length constant and characteristic impedance. Limits of error are ascertained and the accuracy in the measurements is determined.

Vol. 68, No. 401, May, 1930.

Surges and Over-Voltage Phenomena on Transmission Lines due to Lightning. Dr. H. Norinder.

A Direct Reading Photo-Electric Photometer for the Commercial Measurement of Incandescent Electric Lamps. G. T. Winch.

The Development of a Precision Ammeter for very High Frequencies. E. B. Moullin. Instrument measures up to 30,000 kilocycles per second and can carry unshunted a current of any magnitude.

An Ammeter for very High Frequencies. Prof. C. L. Fortescue and L. A. Moxon. A hot wire instrument intended for use at any frequency up to 100 million cycles per second.

A Method of Measuring Mechanical Impedance. Prof. E. Mallett and R. C. G. Williams.

Some Notes on the Design of a Gramophone Pick-up. G. W. Sutton.

Frequency Stabilisation of Valve Oscillators. Prof. E. Mallett.

An Instrument for Projecting and Recording the Response Curves of Electrical Circuits. Prof. C. L. Fortescue and F. Ralph.

Summary (to 1925) of European and American Data on Interference between Power and Communication Circuits. The technical report (Ref. M/T3) of the British Electrical and Allied Industries Research Association. Further information (which will be published as a P.O. Research Report) will be available during this year.

Report of Annual Dinner, 1930.

Journal of the American Institution of Electrical Engineers.

Vol. XLIX., No. 3, March, 1930.

Telephone Interference from A.C. Generators feeding directly on Line with Neutral Grounded. J. J. Smith. It is shown that the triple and non-triple harmonics in the voltage wave shape cause currents which flow in different paths on the power system.

Recent Developments in Toll Telephone Service. W. H. Harrison. Physical and technical phases of the development in recent years of " toll " (trunk in Great Britain) telephone service in America.

Acoustics of Radio Broadcasting Studios. L. E. Voorhees.

Submarine Telegraphy in the Post War Decade. L. S. Coggeshall. Deals with Regenerative Repeaters, loaded cable, 2-element cable recorder code adapted to land-line transmission, cable printer system using 2-element code, Pennot superposed cable carrier apparatus and steps taken to balance a loaded duplex cable.

Volume XLIX., No. 4, April, 1930.

Transoceanic Telephone Service Short-Wave Equipment. Technical features of the new Short-Wave Radio Stations of the Bell System. A. A. Oswald.

Calculation of Induced Voltages in Metallic Conductors. H. B. Dwight.

A Cathode Ray Oscillograph with Norinder Relay. Its design and application. P. Ackermann.

Vol. XLIX., No. 5, May, 1930.

Calculation of Protection of a Transmission Line by Ground Conductors. H. B. Dwight.

Successive Unidirectional Condenser Discharge. Shiro Sano.

Transoceanic Telephone Service. Short-Wave Transmission. Transmission features of Short-Wave Radio Circuits. Ralph Bown. Problems involved in short-wave work over long distances and bases for design of systems. Choice of frequencies, amounts of power, directive antennas, automatic gain controls in receiver and voice-operated switching devices.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	Grade.	Promoted to	Date.
Baldwin, F. G. C.	Assistant Suptg. Engineer, N. District	Superintending Engineer, N. District.	10-8-30
Herbert, T. E.	Assistant Suptg. Engineer, S. Lancs. District.	Superintending Engineer, S. Lancs. District.	1-6-30
Whillis, C.	Assistant Staff Engineer, E.-in-C.O.	Superintending Engineer, Scot. West District.	9-4-30
Ramsay, F. G.	Commander, H.M.T.S. "Monarch."	Submarine Superintendent, E.-in-C.O.	1-5-30
Francis, E. S.	Executive Engineer, N. East District.	Assist. Suptg. Engineer, S. Mid. District.	1-8-30
Partridge, T. T.	Executive Engineer, N. Mid. District.	Assistant Suptg. Engineer, S. Lancs. District.	10-4-30
Scarr, W.	Executive Engineer, Eastern District.	Assistant Suptg. Engineer, N. Wales District.	1-8-30
Fletcher, J. F.	Executive Engineer, S. Lancs. District	Assistant Suptg. Engineer, S. Lancs. District.	1-6-30
Barralet, F. O.	Executive Engineer, E.-in-C.O.	Assistant Staff Engineer, E.-in-C.O.	9-4-30
Taylor, C. A.	Executive Engineer, E.-in-C.O.	Assistant Staff Engineer, E.-in-C.O.	9-4-30
Bramwell, J. T.	Executive Engineer, N. District.	Assist. Supgt. Engineer, N. District.	10-8-30
Flavel, G. H.	Chief Officer, H.M.T.S. "Monarch."	Commander, H.M.T.S. "Monarch."	1-5-30
Pratt, R. O.	Second Officer, H.M.T.S. "Monarch."	Chief Officer, H.M.T.S. "Monarch."	1-5-30
Holland, A. E.	Fourth Officer, H.M.T.S. "Monarch."	Second Officer, H.M.T.S. "Monarch."	1-5-30
Boryer, W. F.	Assistant Engineer, London District.	Executive Engineer, London District.	1-4-30
Watson-Weatherburn, S. W. ...	Assistant Engineer, Scot. East District.	Executive Engineer, N. Mid. District.	27-4-30
Curling, R.	Assistant Engineer, Scot. West District.	Executive Engineer, Scot. West. District.	19-3-30
Speight, A.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	19-3-30
Bastow, F.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	1-5-30
Hembrough, J. R.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	10-7-30
Gregory, H. J.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	1-5-30
Bartlett, A. W.	Assistant Engineer, London District.	Executive Engineer, London District.	1-7-30
Broomhead, A.	Assistant Engineer, S.E. District.	Executive Engineer, N. Mid. District.	4-7-30
Pearson, E. A.	Assistant Engineer, N. Wa. District.	Executive Engineer, S. Wa. District.	1-8-30
Osborn, W. M.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E. District.	1-8-30
Field, A. W.	Assistant Engineer, N.W. District.	Executive Engineer, S. Lancs. District.	To be fixed later.
Day, W.	Assistant Engineer, London District.	Executive Engineer, S. Wa. District.	
Talbot, H. J.	Chief Inspector, London District.	Assistant Engineer, London District.	1-4-30
Cosh, L. G.	Chief Inspector, E.-in-C.O.	Assistant, Engineer, E.-in-C.O.	21-3-30
Roe, E. A.	Chief Inspector, N. Mid. District.	Assistant Engineer, N. Mid. District.	7-5-30
Casemore, G.	Chief Inspector, S. East District.	Assistant Engineer, S. East District.	21-5-30
Gunston, J. A.	Chief Inspector, Eastern District.	Assistant Engineer, Scot. East District.	27-4-30
Lister, B.	Chief Inspector, S. West District.	Assistant Engineer, E.-in-C.O.	2-4-30
Hopps, F.	Chief Inspector, N. Mid. District.	Assistant Engineer, N. Mid. District.	1-6-30
Lambert, S.	Inspector, N. Wales District.	Chief Inspector, N. Wales District.	1-4-30
Fisher, G. E.	Inspector, Scot. West District.	Chief Inspector, N. Ire. District.	1-5-30
Green, W.	Inspector, Eastern District.	Chief Inspector, Eastern District.	30-3-30
Bingham, A. H.	Inspector, S. West District.	Chief Inspector, S. West District.	6-4-30
Smith, P. G.	Inspector, Testing Branch.	Chief Inspector, Testing Branch.	23-1-29
Bocock, W.	Inspector, N. West District.	Chief Inspector, London District.	13-4-30
McIntosh, H. B.	Inspector, Scot. West District.	Chief Inspector, N. Mid. District.	6-4-30
Brooke, C. H.	Inspector, London District.	Chief Inspector, London District.	17-7-29
Thatcher, C. H.	Inspector, N. Mid. District.	Chief Inspector, London District.	20-4-30
Akester, A.	Inspector, N. East District.	Chief Inspector, London District.	1-4-30
Messenger, C. W.	Inspector, London District.	Chief Inspector, London District.	18-9-29
Smith, G.	Inspector, London District.	Chief Inspector, London District.	28-3-30
Cain, S. J.	Inspector, Eastern District.	Chief Inspector, Eastern District.	
Missen, H.	Inspector, E.-in-C.O.	Chief Inspector, E.-in-C.O.	23-3-30
Howe, H. B.	Inspector, London District.	Chief Inspector, London District.	1-10-29
Harris, R.	Inspector, S.W. District.	Chief Inspector, S.W. District.	
Warren, H. G.	Inspector, N.Mid. District.	Chief Inspector, N. Mid. District.	
Hibberd, R. M.	Inspector, N.Mid. District.	Chief Inspector, N. Mid. District.	
Thompson, J. W.	Inspector, S. Lancs. District.	Chief Inspector, N. Mid. District.	To be fixed later.
Reeves, T. F.	Inspector, S. Mid. District.	Chief Inspector, S. Mid. District.	
Stark, W.	Inspector, Scot. East District.	Chief Inspector, Scot. E. District.	
Collins, T. J....	Inspector, S. Mid. District.	Chief Inspector, E. District.	

PROMOTIONS (*Continued*).

Name.	Grade.	Promoted to	Date.
Vick, E. H.	Inspector, S. Lancs. District.	Chief Inspector, S. Lancs. District.	To be fixed later.
Scott, F.	Inspector, N.E. District.	Chief Inspector, N.E. District.	
Mitchell, T. A.	Inspector, London District.	Chief Inspector, S.E. District.	
Hill, R. J.	Inspector, E.-in-C.O.	Chief Inspector, E.-in-C.O.	
Maddocks, D. C.	Inspector, London District.	Chief Inspector, London District.	
Owen, W.	Skilled Workmen, Cl. I. S. Lancs. District.	Inspector, S. Lancs. District.	24-11-29
Robinson, G. D.	Skilled Workmen, Cl. I., Testing Branch.	Inspector, Testing Branch.	4-5-29
David, A. J.	Skilled Workmen, Cl. I., South Wales District.	Inspector, S. Wales District.	21-1-29
Stewart, J.	Skilled Workmen, Cl. I., Scot. West. District.	Inspector, Scot. West District.	23-3-30
Benson, W. K.	Skilled Workmen, Cl. I., S. Lancs. District.	Inspector, S. Lancs. District.	19-1-30
Anderson, T. N.	Skilled Workmen, Cl. I., Scot. West. District.	Inspector, Scot. West District.	8-11-28
Clayton, F. E.			
Webber, R. N.			11-4-29
Scrivener, S. W.	Skilled Workmen, Cl. I., Eastern District.	Inspector, Eastern District.	To be fixed later.
Banyard, S. C.			
Rance, A. W.			
O'Connor, W.	Skilled Workmen Cl. I., Scot. West District.	Inspector, Scot. West District.	To be fixed later.
Blair, A. M.			
Love, R. C.			

APPOINTMENTS.

Name.	From	To	Date.
Lowry, W. R. H.	Open Competition.	Probationary Inspector.	7-4-30
Cook, A.			7-4-30
Turner, H. A.			6-5-30

RETIREMENTS.

Name.	Rank.	District.	Date.
Medlyn, W. J.	Superintending Engineer.	S. Lancs.	31-5-30
Aitken, R.	,, ,,	Scot. West.	31-3-30
Sell, L. J.	Assistant Engineer.	S. East.	18-4-30
Mears, T.	,, ,,	E.-in-C.O.	31-3-30
Dawson, A. E.	,, ,,	N. Mid.	31-5-30
Strong, E.	,, ,,	E.-in-C.O.	27-3-30
Davidson, J.	,, ,,	N. Ireland.	31-3-30
Walker, J. C.	,, ,,	N. East.	31-3-30
Firth, S. S.	,, ,,	N. Mid.	31-5-30
Montgomery, H.	Chief Inspector.	Scot. West.	30-4-30
Mathewson, J. I.	,, ,,	Scot. East.	16-4-30
Briscoe, H. R.	Inspector.	S. Lancs.	31-3-30
Hayward, F. W.	,,	London.	31-3-30
Draper, T.	,,	N. Wales.	21-4-30
Randell, E.	,,	London.	30-4-30

DEATHS.

Name.	Rank.	District.	Date.
Hives, F. G.	Assistant Engineer.	S. Mid.	29-3-30
Taylor, G.	Inspector.	Scot. East.	7-3-30

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	District.	From	To	Date.
Bell, G. W.	E.-in-C.O.	Staff Officer.	Principal Clerk.	1-4-30
Rhodes, H.	,,	Executive Officer.	Staff Officer.	11-4-30
Robinson, W. D.	Research.	Executive Officer.	Staff Officer.	17-5-30
Brown, B. M.	Equipment.	Executive Officer.	Staff Officer.	5-6-30
Buxton, A. D.	Contracts.	Acting Executive Officer.	Executive Officer.	17-5-30
Wilson, P. A. V.	Radio.	Clerical Officer.	Executive Officer, Staff.	5-6-30
Murray, C. E.	Accounts.	Clerical Officer.	Acting Executive Officer, Equipment.	5-6-30
Child, A. J.	E.-in-C.O.	Actg. Executive Officer.	Executive Officer.	26-2-30
La Croix, A.	,,	Clerical Officer.	Executive Officer.	11-4-30
Buxton, A. D.	,,	,, ,,	Actg. Executive Officer.	18-4-30
Timson, J. R.	Ldn.	Executive Officer.	Staff Officer.	1-6-30
Tucker, E. J.	,,	Clerical Officer.	Higher Clerical Officer.	1-5-30
Thorne, H. H.	,,	,, ,,	,, ,,	1-5-30
Lines, E. R.	,,	,, ,,	,, ,,	23-5-30

RETIREMENTS.

Name.	District.	Grade.	Date.
Ryder, A.	N.E.	Higher Clerical Officer.	10-4-30
Hewins, H. J.	N.E.	,, ,,	30-4-30
Ellery, A. Q.	LED.	,, ,,	30-4-30
Rodway, C. H. S.	LED.	Staff Officer.	31-5-30

DEATHS.

Name.	District.	Grade.	Date.
Williams, J. P.	S. Lancs.	Higher Clerical Officer.	25-5-30
Tennant, T. M.	E.-in-C.O.	Staff Officer.	5-5-30

TRANSFERS.

Name.	Grade.	From	To	Date.
Elsworth, C.	Higher Clerical Officer	S. Lancs.	N.E.	25-5-30.

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THE
Post Office Electrical Engineers' Journal

A SIMPLE METHOD OF PRODUCING LOW FREQUENCY CURRENTS OF SINUSOIDAL SHAPE AND THEIR MEASUREMENT.

J. G. Bedford, A.M.I.E.E., and H. Josephs.

TO measure the electrical parameters of lines and apparatus at telegraph frequencies, that is, between 5 and 100 cycles per second, it became necessary to develop a portable generator which would produce an e.m.f. of sinusoidal shape and also be capable of an output up to at least 60 volts.

A simple method of doing this is to use some form of apparatus which gives square-topped reversals, and then eliminate the higher frequency components, thus converting the square-topped waves into sinusoidal ones. The requirements of this type of low-frequency generator may be divided into three parts as follows:—

(1) The provision of a suitable generator giving a square-topped wave with a negligible transit time and constant speed, and capable of speed regulation over the required range.

(2) The provision of a suitable filter to convert the square-topped waves into sinusoidal waves.

(3) The provision of a suitable frequency measuring device which will enable measurements of frequency to be accurately and rapidly made.

With regard to (1): a motor-driven type of Baudot distributor fulfilled this requirement fairly satisfactorily. The governor was removed in order to obtain a sufficient range of speed and an oscillographic test showed that the transit time was negligibly small. The Baudot distributor was driven by a series-wound D.C. motor, requiring up to 220 volt supply and 0.3 amp. The speed of the motor was regulated by means of a 1200 ohm slide wire resistance joined in the supply circuit. For frequencies from 4 to 40 cycles per second the 110 volt supply is suitable, and from 40 to 100 cycles per second the 220 volt supply is suitable.

The front plate of the distributor was removed and the motor drives the brushes over the face of the back plate by a belt and through the epicyclic gear. Ring 2 is connected to the output terminal and + and − battery are joined to the 22 segments of Ring 5. Alternate segments of Ring 5 are connected together, and to the + and − poles of the battery. A spark quench arrangement is connected across the battery and contact brushes.

A schematic diagram of the arrangement is shown in Fig. **1**, and a photograph of the Baudot distributor is shown in Fig. **2**. For a detailed description of this piece of apparatus see Herbert's "Telegraphy," pages 467-470, 3rd Edition, 1916.

With regard to (2): a low-pass filter fulfilled this requirement satisfactorily. In the case of the lowest frequencies, from 8 cycles per second downwards, a two-section filter is necessary if

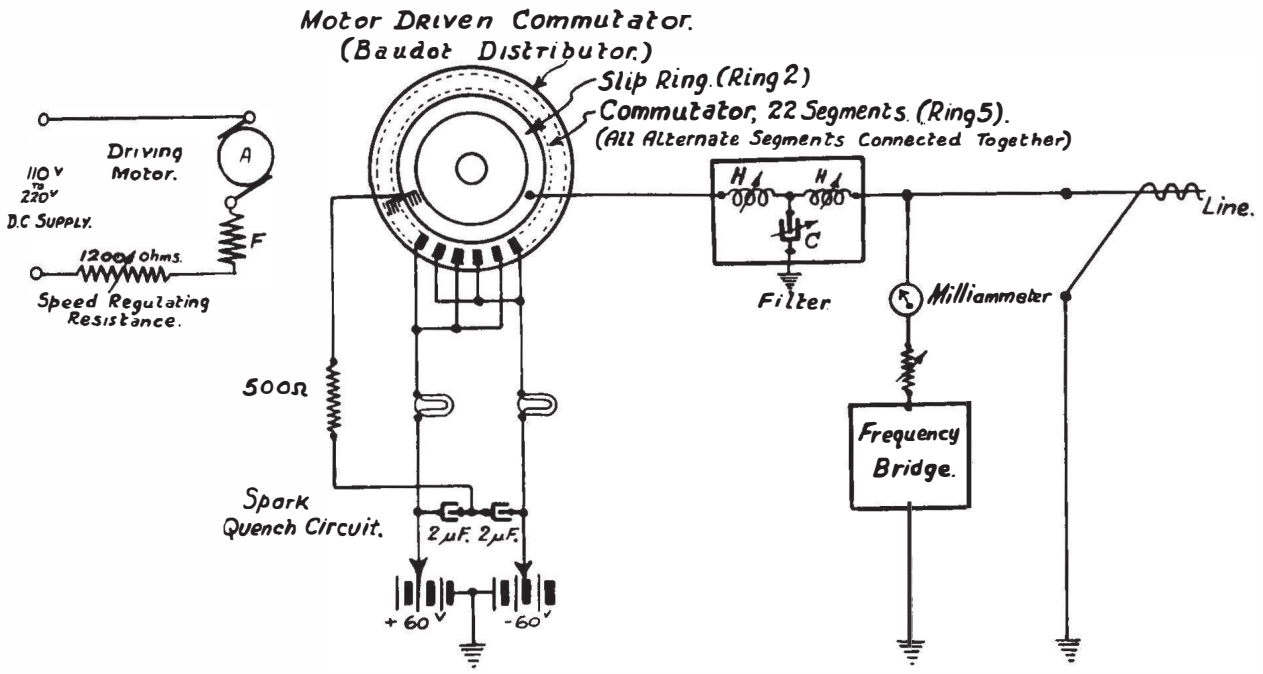


FIG. 1.—CIRCUIT DIAGRAM.

pure sinusoidal shape be required. Above 8 cycles per second a one-section filter only is required. Also above 15 cycles, one value of inductance will suffice for all frequencies up to 100 cycles, but a different capacity value should be used for each frequency band of 10 cycles.

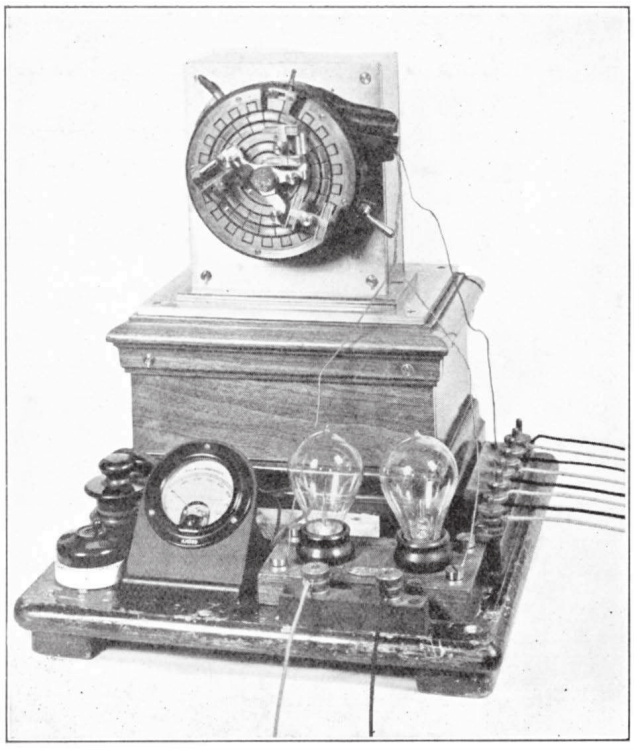


FIG. 2.—BAUDOT DISTRIBUTOR ADAPTED.

Four inductances, each having a value of 6 henries are required to cover the frequency range from 9 to 100 cycles, and four additional coils—two having an inductance of 6 henries each and two of 18 henries each are needed if it be necessary to go below 9 cycles per second. The inductance elements used consisted of coils wound on laminated iron stampings with an air gap in the centre leg and an $\frac{R}{L}$ value of 10.

One condenser only is required for each single section filter from 9 to 100 cycles. Below 9 cycles per second, a condenser of 40 μF capacity is required for each of the two sections of the filter. A type of condenser with tin foil and waxed paper insulation was used.

A three-position telephone key is used for switching in the inductance required for a particular frequency range. Fig. **3** gives the arrangement of plugs and key for the various frequency bands, and also gives the values of the filter elements. From Fig. **3**, it may be seen that the appropriate filter for a particular frequency is connected into the output circuit by

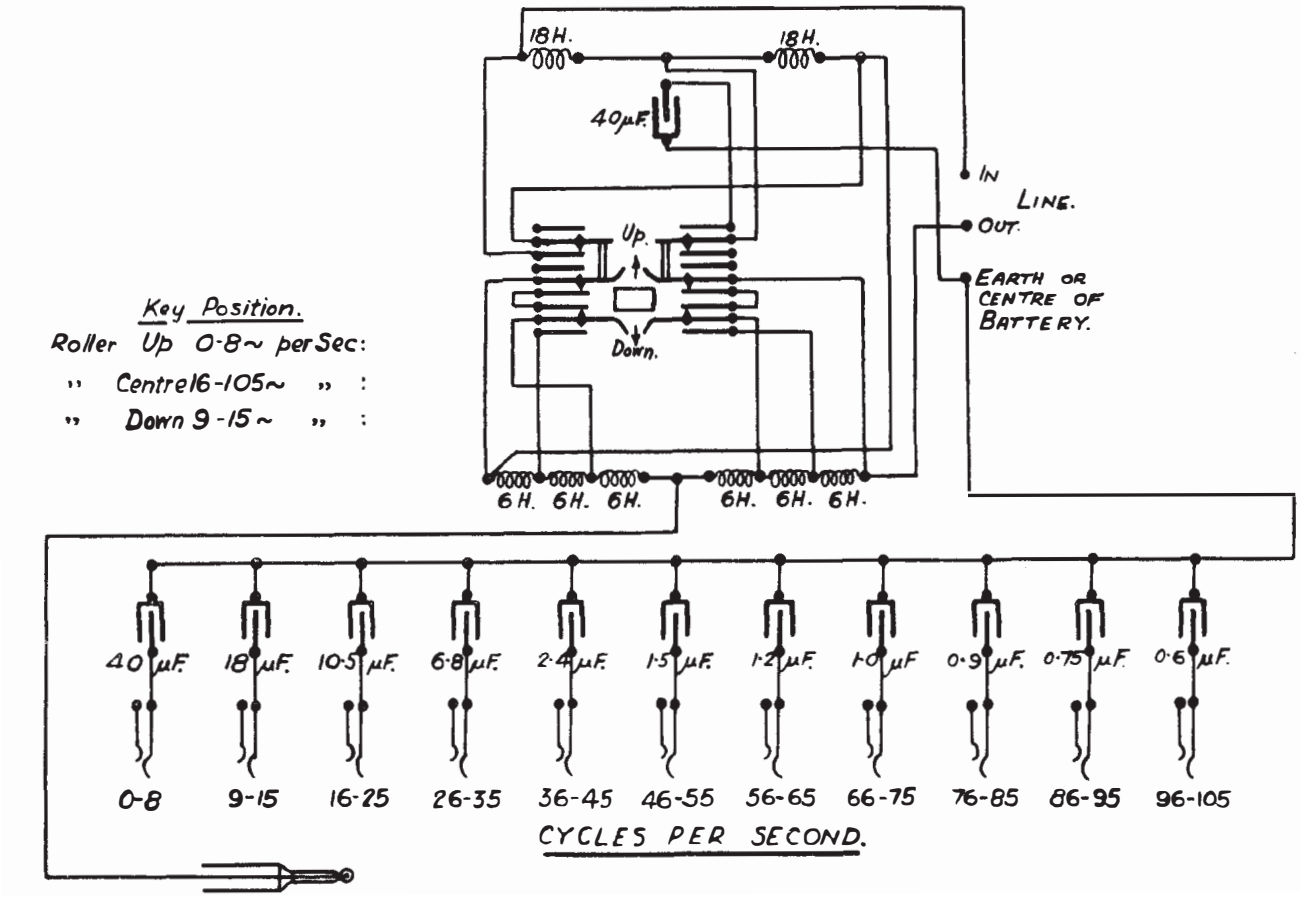

18H.
18H.
40μF.
IN LINE.
OUT.
EARTH OR CENTRE OF BATTERY.
Up.
Down.
Key Position.
Roller Up 0-8~ per Sec:
" Centre 16-105~ " :
" Down 9-15~ " :
6H. 6H. 6H.
6H. 6H. 6H.
40 μF. 18 μF. 10·5 μF. 6·8 μF. 2·4 μF. 1·5 μF. 1·2 μF. 1·0 μF 0·9 μF. 0·75 μF. 0·6 μF.
0-8 9-15 16-25 26-35 36-45 46-55 56-65 66-75 76-85 86-95 96-105
CYCLES PER SECOND.

FIG. 3.—SHOWING INDUCTANCES AND CAPACITIES FOR VARIOUS FREQUENCIES.

means of the telephone key and the insertion of a plug into the appropriate condenser jack.

With regard to (3): an adaptation of Maxwell's Commutator Bridge method is convenient for the measurement of low-frequencies of the order of from 4 to 100 cycles per second.

The network is shown diagrammatically in Fig. 4, and is similar to the well-known Wheatstone bridge arrangement, except in respect to the arm BD. The points B and D are connected to the local contacts (indicated by "*x*" and "*y*" in Fig. 4) of a standard "B" relay. Condenser C is a good mica condenser, one terminal of which is connected to the tongue of the relay and the other to contact "*x*" and point D. G is a ballistic galvanometer, and in this case was a Tinsley portable instrument of 512 ohms resistance with a figure of merit of 17 mm. per micro-amp, and a periodic time of two seconds. In practice it was found convenient when measuring the lower frequencies

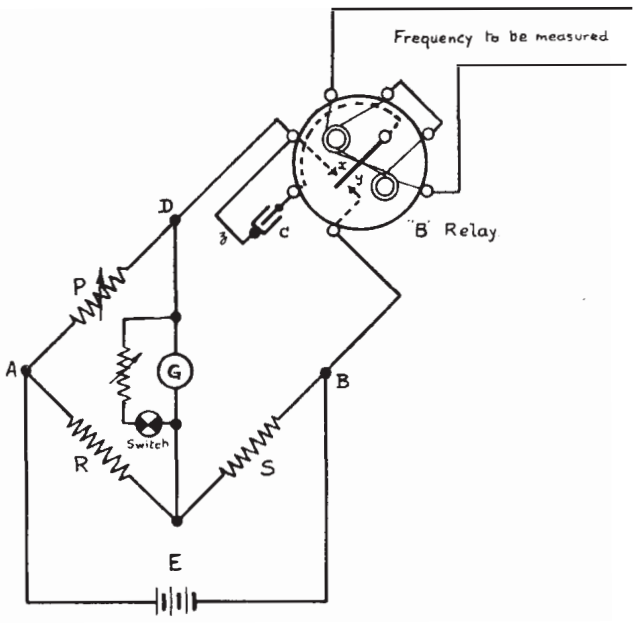


FIG. 4.—BRIDGE CONNECTIONS.

to shunt the galvanometer by a slide wire resistance in order to produce a steady deflection. P is an adjustable resistance (an F rheostat is convenient) and R and S are fixed resistances, and for low-frequency ranges resistance coils in metal cases are suitable. A battery is connected between the points A and B. The frequency supply under test is joined to the line terminals of the " B " relay, as shown in Fig. 4, and the current through the coils is adjusted to a suitable value.

The function of the relay tongue is to allow the condenser C to be charged and discharged at the periodicity of the supply under test. When the tongue is on the contact " *y*," the condenser is charged from the battery. When the tongue is on the contact " *x*," the condenser discharges itself *via* the connection ωx, the contact and tongue, to the other plate of the condenser. During the charging period a transient charging current will flow through the various arms of the bridge, part of which flows through P and part through R and G in series.

During the discharging period no appreciable amount of the transient current will flow through the galvanometer G, because the resistance of the connection ωx is negligibly small compared with the component parts of the bridge.

Due to the vibration of the tongue between the contacts " *x* " and " *y* " there will be a succession of momentary currents through the galvanometer G. In addition to these momentary currents there is a steady current through G during the whole time. If the summation of both the transient and steady currents through the galvanometer G over the whole time be zero the deflection of the galvanometer will be zero, provided the galvanometer is sufficiently ballistic. This condition is dependent upon the value of the condenser C, the periodicity *f*, and the values of the resistances P, R, and S. The relationship between these quantities is given in Maxwell's " Treatise on Electricity and Magnetism," 2nd Edition, Vol. II., pp. 776 and 777. The relationship there given is only an approximation and is not in a convenient form to be used by the engineer. Maxwell based his analysis on his dynamic theory in which currents play the rôle of velocities, and expressions are set up for the kinetic energy, potential energy, and dissipation, etc. The balancing relationship is then deduced from general dynamic equations. A mathematical investigation on modern lines has been made and is given in the Appendix.

It is there shown that,

$$f = \frac{R}{SPC}$$

where

f = frequency of the supply in cycles per second.
C = capacity of the condenser in Farads.
P = resistance of the adjustable arm in ohms.
S and R = fixed resistances in ohms.

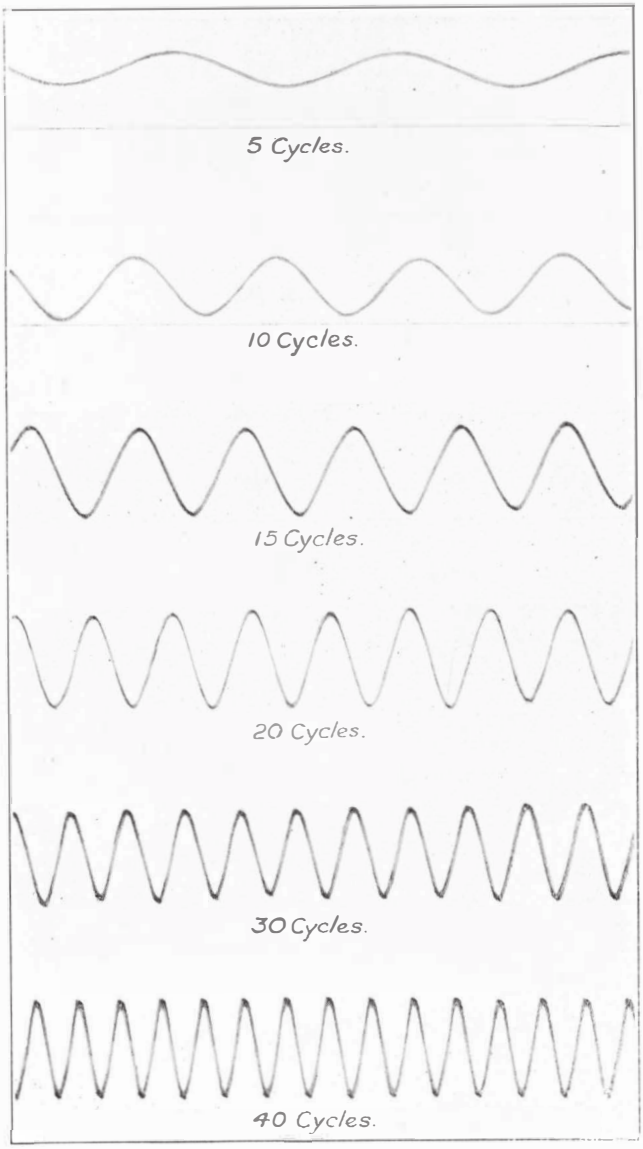


FIG. 5.—OSCILLOGRAMS SHOWING WAVE SHAPES AT DIFFERENT FREQUENCIES.

The ratio $\frac{R}{S}$ should be small, *i.e.*, of the order of $\frac{10}{1,000}$ or $\frac{10}{10,000}$.

R and S were 10 and 1,000 ohms respectively and P a Rheostat F, C was a 1 μF fixed mica condenser and E an accumulator battery of 20 volts. These values gave a convenient range of P from 2,500 ohms to 100 ohms for a frequency range of from 4 to 100 cycles per second. A calibration card for values of P was fixed near the bridge for ready reference.

The arrangement described is simple to manipulate and the adjustments necessary in changing from one frequency to another are rapidly made. A good sinusoidal wave shape is obtained and a Fourier analysis of oscillographic records of wave shapes down to 5 cycles per second, (see Fig. **5**), showed that throughout the range waves were completely free from harmonics of any description. Measurements made on oscillograms showed that a precise frequency regularity was obtained. In conclusion, it should be noted that a very wide range of output voltage and consistency of frequency is available by the arrangement described in this article; advantages which cannot be readily obtained by thermionic valve methods.

APPENDIX.

In order to deduce an expression giving the balancing relationship for the frequency bridge described in this article, first consider the equivalent circuit for the charging period, shown in Fig. **6**.

Let u, v and w denote the cyclic currents in the meshes and I_5 the current through the ballistic galvanometer G.

Also put $Z_1 = P$

$$Z_2 = \frac{1}{pc} \text{ where } p \equiv \frac{d}{dt}$$

$Z_3 = S$

$Z_4 = R$

$Z_5 = G$ the galvanometer resistance

$Z_6 = B$ the battery resistance.

From Kirchhoff's law we have,

$$\left.\begin{aligned} u(Z_3+Z_4+Z_6) - vZ_3 - wZ_4 &= E \\ -uZ_3 + v(Z_2+Z_3+Z_5) - wZ_5 &= O \\ -uZ_4 - vZ_5 + w(Z_1+Z_4+Z_5) &= O \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

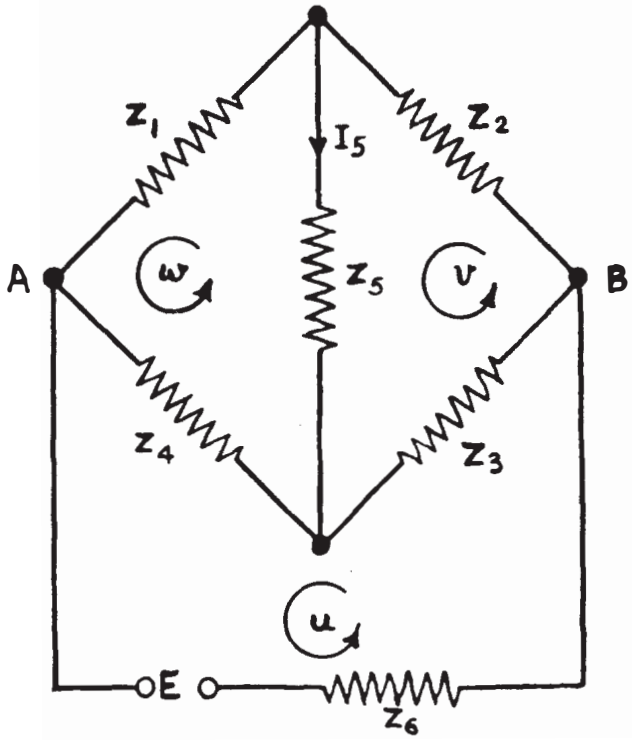


FIG. 6.—BRIDGE NETWORK, CYCLIC CURRENTS AND RESISTANCES.

Substituting $v = w + I_5$ and rearranging we get the determinant

$$I_5 = \frac{\begin{vmatrix} E-(Z_3+Z_4) & (Z_3+Z_4+Z_6) \\ O \quad (Z_2+Z_3) & -Z_3 \\ O \quad (Z_1+Z_4) & -Z_4 \end{vmatrix}}{\begin{vmatrix} -Z_3 & -(Z_3+Z_4) & (Z_3+Z_4+Z_6) \\ (Z_2+Z_3+Z_5) & (Z_2+Z_3) & -Z_3 \\ -Z_5 & (Z_1+Z_4) & -Z_4 \end{vmatrix}}$$

Evaluating the above determinant we get

$$I_5 = \frac{E\left(PS - \frac{R}{pC}\right)}{\frac{1}{pC} \cdot K_1 + K_2 + K_3} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where

$$K_1 = SR + PS + PR + PB + RB + SG + RG + GB$$

$$K_2 = S(PR + PB + RB + PG + GB)$$

$$K_3 = G(PR + PB + RB)$$

Equation (2) may be solved by the Heaviside operational method.

Putting E = 1, we may write.

$$\frac{PS-\frac{R}{pC}}{\frac{1}{pC}\ K_1+K_2+K_3}(1)\equiv \frac{1}{Z(p)}_{p=0}+\sum_{K=1}^{K=n}\frac{e^{p_K t}}{p_K\frac{\partial Z(p)}{\partial p}_{p=p_K}}\ldots(3)$$

where

(1) = Unit discontinuous function.
$Z(p)$ = Generating impedance function.

Now

$$Z(p)=\frac{K_1+pCK_2+pCK_3}{pCPS-R}$$

$$\therefore\ p_1=-\frac{K_1}{C(K_2+K_3)}$$

and

$$p_1\frac{\partial Z(p_1)}{\partial p}=\frac{1}{\left(\frac{PS}{K_2+K_3}+\frac{R}{K_1}\right)}$$

Hence, for I_5, the current through the galvanometer, we obtain,

$$I_5=E\left\{\frac{PS}{K_2+K_3}+\frac{R}{K_1}\right\}exp\left(-\frac{K_1 t}{C(K_2+K_3)}\right)-\frac{ER}{K_1}\ \ldots\ldots\ldots(4)$$

where

t = time in seconds, measured from the instant that the relay tongue first touches the contact y.

E = e.m.f. of battery of resistance B.

The equation for I_5 consists of two parts, one of which is the steady current component, and the other the transient current that flows through the galvanometer whilst the condenser is being charged. Now the condenser is charged and discharged f times per second and it may be seen that the condition for a balance is such that,

$$\lim_{t\to\infty} I_5 = 0$$

From this condition we obtain,

$$\frac{E/C(K_2+K_3)}{K_1}\left\{\frac{PS}{K_2+K_3}+\frac{R}{K_1}\right\}=\frac{ER}{K_1}$$

$$\therefore\ f=\frac{R}{SPC-\frac{CR(K_2+K_3)}{K_1}}\ \ldots\ldots\ldots(5)$$

Neglecting the very small battery resistance B, equation (5) may be written,

$$f=\frac{R}{SPC-\frac{CPR\left\{S\left(1+\frac{G}{R}\right)+G\right\}}{P\left(1+\frac{S}{R}\right)+S\left(1+\frac{G}{R}\right)+G}}$$

Using the values given in the article it is found that the quantity

$$\frac{CPR\left\{S\left(1+\frac{G}{R}\right)+G\right\}}{P\left(1+\frac{S}{R}\right)+S\left(1+\frac{G}{R}\right)+G}$$

is negligibly small compared with SPC.

Hence we obtain the balancing relationship

$$f=\frac{R}{SPC}\ \ldots\ldots\ldots(6)$$

where

f = frequency of the supply in cycles per second.
C = capacity of the condenser in Farads.
P = resistance of the adjustable arm in ohms.
S and R = fixed resistances in ohms.

THE EFFECT OF NOISE ON THE ARTICULATION OF A TELEPHONE CIRCUIT.

JOHN COLLARD, Ph.D., B.Sc. (Eng.).

INTRODUCTION.—At the present time the C.C.I.* and the C.M.I.† are considering the question of fixing permissible limits for the noise in telephone circuits. Considerable attention is, therefore, being directed towards the subject of noise measurement. In the past, it has been the custom to rely almost exclusively on subjective methods of measuring noise in which the personal judgment of the operator played a very important part. In this type of measurement different operators may obtain widely differing results for the same line noise, and even the same operator may obtain different results on different occasions. These variations are reduced to small values when trained operators are used, and the whole of the present international telephone network has been built up with the aid of such methods of noise measurement. In many instances, however, trained operators are not available and some objective method of measurement is therefore to be desired. This is particularly the case where noise is due to induction from a neighbouring power system, since a power engineer, on being accused of causing noise in the telephone circuit, not unnaturally desires to ascertain for himself the extent of the trouble. Usually the power engineer has had little experience in the measurement of noise so that the values he obtains may differ considerably from the values claimed by the telephone engineer. These differences may make it difficult for the two engineers to arrive at an amicable agreement, especially if it is a question of deciding whether or not the noise exceeds a permissible limit.

Since the ultimate effect of noise in a telephone circuit is to reduce the articulation obtainable over the circuit, it is generally accepted that the logical criterion of the interfering effect of noise is the reduction in articulation produced in some standard circuit. The choice of a method for the measurement of noise must therefore be based on a detailed knowledge of speech and the effect of noise on articulation.

A general study of articulation and noise is at present being undertaken by the International Telephone and Telegraph Laboratories, Inc., and it may be of interest to give here an outline of some of the results of this study already obtained.

One result of this work has been the development of a technique for the calculation of the articulation for any telephone circuit from a knowledge of the constants of that circuit. This has been used in the present paper to calculate

* *Comité Consultatif International des Communications Téléphoniques à Grande Distance.*

† *Commission Mixte Internationale Pour les Expériences Relatives à la Protection des Lignes de Telecommunication et des Canalisations souterraines.*

certain values of articulation and, since the technique is comparatively new, two examples have been given here to show that good agreement is obtained between actual measured values of articulation and results calculated by means of the technique. Fig. **1** shows measured and

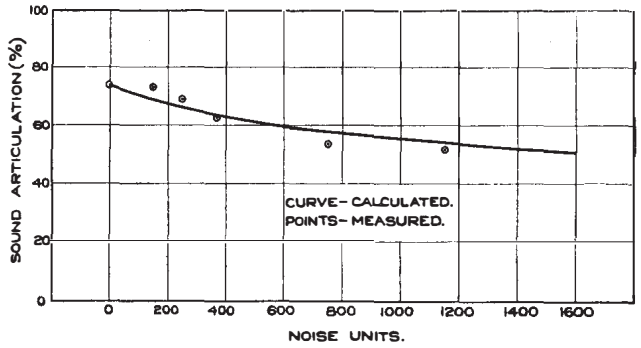


FIG. 1.

calculated values of sound articulation for an ordinary circuit between two subscribers with a 20 db. trunk and with different amounts of line noise entering the apparatus of the listening subscriber. The noise in this case was complex in form, having components spaced at intervals of 120 cycles per second. Fig. **2** shows the per-

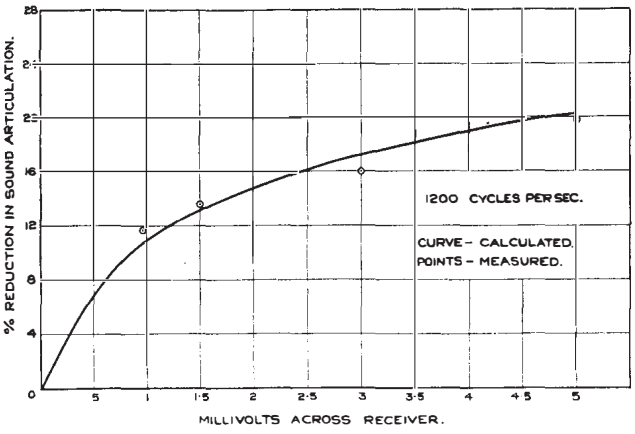


FIG. 2.

centage reduction in sound articulation obtained in a similar circuit to Fig. **1**, except that a 26 db. trunk was used and a pure tone of 1200 cycles per second was used as the noise. In both cases it will be seen that the measured points fall reasonably close to the calculated curves, the differences that occur are, to a large extent, due to the errors inherent in any articulation test.

In these two examples, sound articulation has been used because the tests happened to have been made in terms of this quantity. The results that follow in this paper, however, have been expressed in terms of the syllable articulation obtained with the Esperanto Logatome lists proposed by the 4th Commission of the C.C.I.

Speech and Noise.—If the frequency spectrum of an elementary speech sound is studied, it will be found that the prominent components occur grouped together in one or more frequency regions or bands. These are called the characteristic bands of speech and it appears that a listener when receiving speech sounds, first subconsciously determines at what frequencies the characteristic bands occur and thence recognises what sounds have been transmitted to him. His ability to understand speech thus depends essentially on the success with which he recognises the individual characteristic bands. When one subscriber is talking to another over a telephone circuit, the characteristic bands produced by the talker are transformed into electrical energy and transmitted to the other end of the circuit where they are transformed again into acoustical energy and reach the listener's ear. In their passage from the talker to the listener the characteristic bands suffer a certain amount of distortion, due to the constants of the circuit. Each characteristic band reaching the listener's ear causes his basilar membrane to vibrate, the position of maximum vibration depending on the frequency of the band. When noise is present in the circuit it is transformed into acoustical energy by the receiver and sets into vibration those portions of the basilar membrane corresponding to the frequencies present in the noise. If that part of the basilar membrane corresponding to a given characteristic band is already being caused to vibrate at considerable amplitude by noise, then, when the characteristic band reaches the listener's ear, the additional vibration due to it may not be perceived. In other words, this particular characteristic band will play no part in assisting the listener to distinguish one sound from another, since it has been masked by the noise. Since the articulation obtainable over a given telephone circuit is directly dependent on the number of characteristic bands that the listener is able to recognise successfully, it follows that the masking of

certain characteristic bands by noise will result in a reduction of articulation.

Figs. **3**, **4** and **5** have been prepared to illustrate this point more fully. Fig. **3** shows the distribution, both as regards frequency and magnitude, of the characteristic bands reaching a listener after transmission over an ordinary telephone circuit. Each dot does not represent a characteristic band, but the number of dots in any given area is proportional to the frequency of occurrence of the characteristic bands in that region. The magnitude of the bands has been expressed in sensation units, *i.e.*, the number of decibels that the band is above threshold. The dots are most closely clustered together in the region from 400 to 800 cycles per second, so that

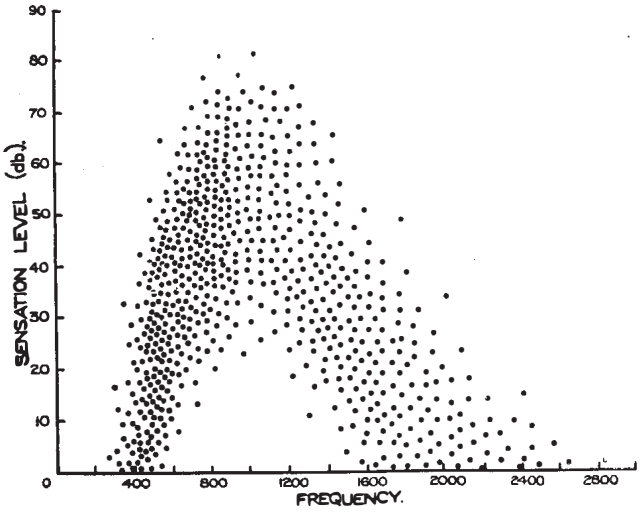


FIG. **3**.

this frequency range is very important from the articulation point of view. At the higher and lower frequencies, not only are the dots less closely spaced, but there are very few above threshold. These frequency ranges therefore play a relatively small part in assisting articulation over the normal telephone circuit. In the range 600 to 1400 cycles per second all the dots are well above threshold owing to the fact that at these frequencies the combined efficiency of the transmitter, circuit, receiver and ear is at a maximum.

Fig. **4** shows the effect of an 800-cycle tone when introduced into the circuit. The sensation level of the tone has been taken as 60 db. The shaded area indicates the area over which the

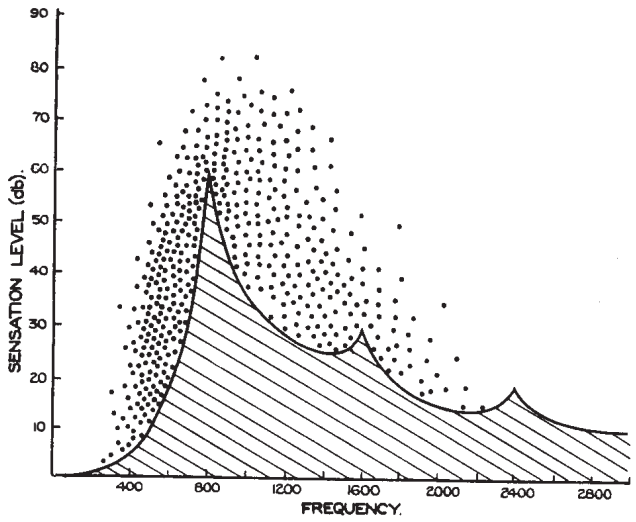


FIG. **4**.

masking occurs, *i.e.*, any characteristic band having a frequency and level such that it falls within the shaded area will be inaudible owing to the presence of the noise in the circuit. The peaks in the masking curve at 1600 and 2400 cycles per second are due, of course, to harmonics introduced in the listener's ear by asymmetric distortion. An approximate idea of the percentage reduction in the number of characteristic bands reaching the listener due to the presence of the noise can be obtained by subtracting the number of dots shown in Fig. **4** from the number shown in Fig. **3** and then dividing this by the number of dots in Fig. **3** and multiplying by 100. In the case shown here the reduction is about 33% and, since this corresponds to a reduction in logatome articulation of about 30%, this amount of noise in an actual case would obviously be quite prohibitive.

Fig. **5** has been prepared to show what occurs when a number of single frequency tones are present together in the circuit. Three tones, 400, 1000 and 2000 cycles per second, are shown. In this case each tone produces its own masking curve and, if the magnitude of the tones are small as they would be in an actual case, there is practically no overlapping of the individual curves. The total number of characteristic bands masked out by the three tones together is therefore equal to the sum of the numbers masked out by the individual tones when present separately in the circuit. We can say, therefore, that the effect on articulation of a number

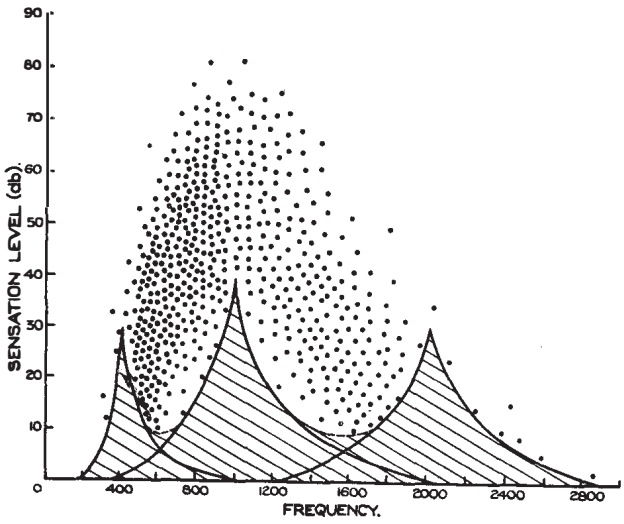


FIG. 5.

of tones when present together in a telephone circuit is equal to the direct sum of the effects produced by each tone when alone in the circuit.

The Addition of Noise.—This question of the addition of the different components in a complex noise from the point of view of articulation reduction is important, and it is therefore proposed to consider it in this section in rather more detail.

Consider, first of all, the effect of introducing a single frequency tone, say 800 cycles per second, into a telephone circuit, and suppose that this tone is gradually increased in amplitude from a very small value. At first, when the tone is small, the masking curve produced by it will not reach high enough up to mask any of the characteristic bands. As it is increased, however, the masking curve will just begin to mask some of the lower bands, but, since the bands in this region do not occur very frequently, the reduction in articulation will be small. As the tone is still further increased, the masking curve will begin to reach up into the area where the characteristic bands occur more frequently and the articulation reduction will therefore increase more rapidly than at first. Finally, for very large amplitudes, the masking curve will cover characteristic bands over a very large frequency range, resulting in a very rapid deterioration of the articulation. In order to show this point with greater clearness, two curves have been calculated to show the effect of introducing single frequency tones into an ordinary telephone circuit. These curves are given in Fig. **6**, one of them being for 400 cycles per second and the other for 1200 cycles per second. The circuit for which this calculation was made was one consisting of two sets of ordinary subscribers' apparatus with a connecting trunk of 30 db. These curves have been calculated over a range of articulation reduction extending up to 5%. Since this value is about the maximum that can be tolerated, we are not very much interested in values above it. It will be seen from these curves that the relation between articulation reduction and the voltage of the disturbing tone is not linear, although the curves do not depart very much from a straight line. The curve of Fig. **2** shows that over a wider range of articulation reduction the departure from a straight line is much greater.

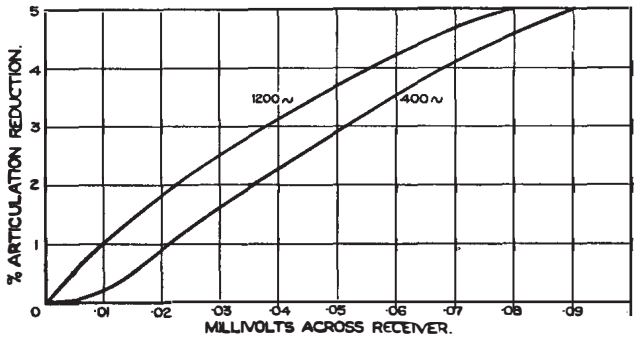


FIG. 6.

In order to study the additive effect of single frequency tones a number of examples have been worked out in which the articulation reduction has been calculated for the circuit mentioned above, first with different single frequency tones present in the circuit alone and then with a number of these present together. The results of these calculations are given below in the following tables. Values of articulation reduction are given, first of all for each of the components when present alone in the circuit, and then for all the components present together in the circuit. For comparison with this last value, two other values are given. The first of these is obtained by adding together directly the articulation reductions due to the individual component when present alone in the circuit. The second value is obtained by taking the square root of the sum of the squares of these individual values.

TABLE I.

Frequency.	Sensation Level.	Percentage Articulation Reduction.			
		Actual value for individual components when present separately.	Actual value for all components when present together.	Direct sum of values for individual components.	Square root of sum of squares of values for individual components.
400	20	5.6	10.0	10.8	7.5
800	40	5.2			
800	40	5.2	8.2	8.5	6.1
1000	40	3.3			
800	30	1.0	4.0	3.9	2.3
1000	30	1.0			
1200	30	1.9			
800	30	1.0	6.6	6.2	2.9
900	30	0.9			
1000	30	1.0			
1100	30	1.4			
1200	30	1.9			

The above examples have been chosen so that they cover a range of total articulation reduction from 4 to 10%. It will be seen from these examples that, even when the different frequencies are spaced only 100 cycles apart, the resultant articulation reduction is practically equal to the direct sum of the individual articulation reductions. The square root of the sum of the squares is in every case too small, the error varying from about 25 to 55%. As a final check on this point, an analysis of typical line noise which actually occurred in practice has been taken and the articulation reductions for this have been worked out. The values are given in the following table and confirm the previous statements:—

TABLE II.

Frequency.	Relative Amplitude.	Percentage Articulation Reduction.			
		Actual value for individual components when present separately.	Actual value for all components when present together.	Direct sum of values for individual components.	Square root of sum of squares of values for individual components.
320	11	0.2	13.0	13.2	7.8
440	110	2.6			
720	26	6.8			
920	13	1.6			
1030	9	2.0			

Conclusions.—The most interesting result of the work described here is the fact that when noise consists of a number of components at different frequencies, the total interfering effect of the noise is proportional to the direct sum of the effects produced by each component separately. This fact does not appear to have been generally realised before and it has generally been assumed in the past that the square root of the sum of the squares should be taken. In the Telephone Interference Factor Meter of H.S. Osborn, for example, a thermocouple is used as the integrating device.

This direct additive effect applies to most types of line noise such as are usually encountered in telephone circuits subject to induction from neighbouring power lines. There are, however, a few particular cases where this direct addition is not altogether correct. If the frequencies of the different components are sufficiently close together and their amplitudes are sufficiently great, then it is possible for the masking curves of the components to overlap to some extent and where this occurs the direct addition does not hold.

If the masking curves overlap to a large extent, the resultant interfering effect is probably more nearly the root square value than the direct sum. If the overlapping is only partial, the true resultant is somewhere in between the root square value and the direct sum.

An example where the different components are close together is the case of babble which is produced in a telephone circuit by the combined effect of cross-talk from a large number of other circuits. The cross-talk from any one circuit will probably consist of components which are sufficiently widely spaced to give the direct additive effect. The components from different circuits, however, are very likely to occur close together. A further case where the direct addition may not hold exactly is room noise due to traffic in large towns or due to a number of typewriters being operated simultaneously. In such cases the best result would probably be obtained by dividing the whole frequency range into a number of narrow bands, taking for each band the root square value and then adding directly the values for the different bands.

This suggests that a suitable instrument for the measurement of noise might consist of a series of band-pass filters to which a thermo-

couple or valve voltmeter could be switched in turn. Readings would then be taken for each filter and added together directly. If the components of any complex noise were close enough together to fall within the range of a given filter they would be added by the measuring device as the root square value, whereas if components were widely enough spaced so that each came in the range of a different filter they would be added directly. If some components were close together and some widely spaced, then the proper form of addition for each would be obtained by the use of such an instrument. The practical realisation of such a device would appear to be extremely difficult, however, and possibly a simple form of instrument embodying a weighting filter and a square law measuring device could be used, the filter being so arranged as to weight each frequency by a factor rather greater than its actual interfering effect. Such a device, however, would give values of noise which were too high in the case of single frequencies and rather too low if there were a large number of components. The factors could possibly be arranged, however, so that they gave about the right value for most ordinary cases.

The relation between the amplitude of a single frequency tone and the articulation reduction it produces is such that a curve giving the relative interfering effect of different single frequency tones will be different for different amplitudes of the tones. Any network used in an instrument for the objective measurement of noise for weighting the different frequency components according to their interfering effect can obviously only operate according to one fixed curve. Hence the instrument will give indications which are incorrect for all amplitudes of tone except one. Fortunately, as shown here, the curves of articulation reduction against amplitude do not depart very much from a straight line for small values of tone such as are encountered in practice. Errors of this nature will therefore be small.

In this connection it is interesting to notice that there are two ways of defining the relative interfering effect of noise. The first is to take the articulation reduction produced by a fixed voltage. The second is to take the voltage required to produce a fixed articulation reduction. These two definitions do not give exactly the same curves of relative interference for the reasons given in the previous paragraph. In the past it has been the custom to take the first definition, although actually it would appear better to adopt the second one. We are interested chiefly in noise which falls somewhere near the permissible limit; in the case of noise very much less or very much more than this limit we do not require to know its value so accurately. The best definition to take would seem to be the voltage required to produce the maximum permissible reduction in articulation, in whatever circuit is chosen as standard.

The diagram of Fig. **3** was constructed for a particular type of circuit and applies only to that type. For any other type of circuit a different distribution of the dots would be obtained. Since the interfering effect of any frequency is proportional to the number of dots covered by its masking curve, it follows that the same frequency will produce different interfering effects in different circuits. A curve of relative interfering effect obtained for an ordinary telephone circuit would not, therefore, apply to a high quality broadcasting circuit; nor could the curve for the high quality circuit be used for the ordinary telephone circuit. It may be necessary in practice to produce two curves of relative interfering effect, one for an ordinary circuit and another for a high quality circuit.

The explanation given here of the way in which noise in a telephone circuit produces a reduction in articulation leads to rather an interesting conclusion. It is usually assumed that the effect of line noise is to annoy the listener in some way and hence to render him less able to concentrate on what is being said to him. In fact, the expression, the annoying effect of noise, is often used. Actually, however, as will be clear from the description given in this paper, the effect of noise is merely to prevent some of the characteristic bands from being perceived by the listener. He is, therefore, left with fewer clues from which to distinguish one speech sound from another, and consequently obtains a smaller value of articulation. Any annoyance that the listener may experience is thus the result of the articulation reduction rather than the cause of it. That this is so is shown by the close agreement between the calculated and measured values of articulation reduction due to noise, since the calculated values are based only on the ordinary masking curves and include no annoyance factor.

A NOVEL DEVELOPMENT OF CONFERENCE FACILITIES.

W. R. BEACH, Wh. Sch., A.C.G.I., D.I.C.

APART from making long distance telephony a comparatively simple matter, the introduction of telephone repeaters has widened the scope of omnibus circuit facilities and more particularly, conference facilities.

In this connection, Messrs. Paul E. Derrick, Advertising Agents on behalf of Messrs. John Walker & Sons, Ltd., applied for suitable telephone facilities to enable them to give in several towns simultaneously with the actual playing of the Test Matches, what, in effect, is a visual running commentary. The progress of the Match was intended to be indicated on a " Score Recording Board " which would show not only the state of the play, but also the names of the bowler, batsmen, fielder and a ball in motion, following as nearly as possible the movements of the actual game.

In order that the scheme should be successful it was considered essential to provide high grade transmission circuits in balanced cables and as all the towns where Score Recording Boards were proposed to be placed could be reached by means of the main cable network, the application was accepted and the facilities provided in the following manner :—

At the outset, the main trunk circuits and local ends to the Score Recording Boards and the cricket grounds, indicated in Fig. 1 (with the exception of the circuits to Portsmouth and Margate, which were provided later) were set up and omnibus repeaters were made available at the Derby, Manchester and London Repeater Stations. In the case of a particular Test Match, it was then only necessary to select those circuits required and to make any special apparatus changes to meet the requirements for the individual Match.

The first Test Match was played at Nottingham, and Score Recording Boards were displayed at Nottingham, Manchester and Blackpool. Originally, it was intended to include Leeds and not Blackpool, but, with only a few days' notice, Blackpool was substituted, and on all subsequent occasions modified requirements

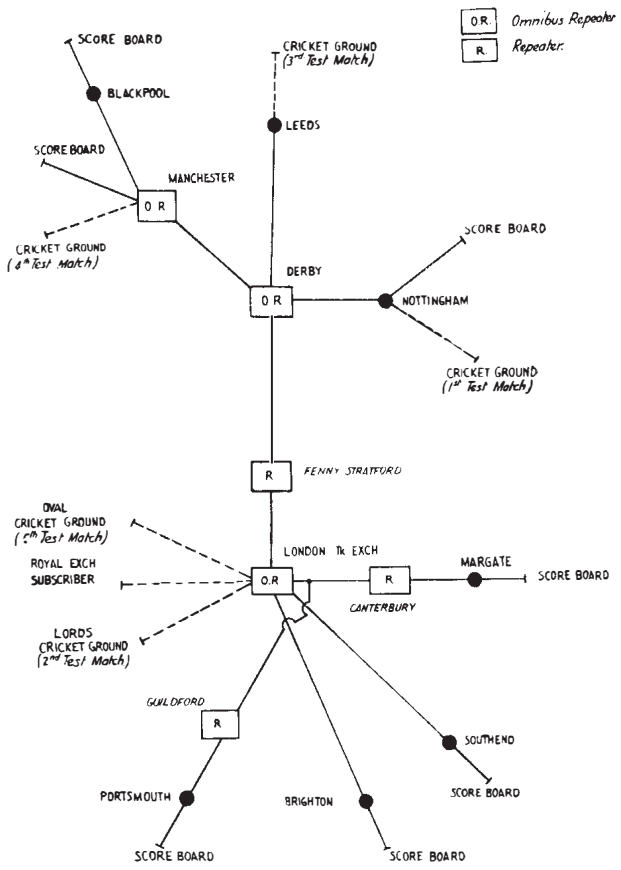


FIG. 1.—GENERAL CIRCUIT ARRANGEMENTS.

at short notice had to be met, owing to the difficulties of the applicants in regard to sites and permissions. The first trial was so successful that a crowd of over 15,000 spectators congregated at the Manchester board on the last day of the Match, in consequence of which, objection was taken locally and it was not possible to arrange an alternative site in time for the second Match.

The second Test Match was played at Lord's Cricket Ground, and Score Recording Boards were displayed at Southend and Brighton. This necessitated the use of the omnibus repeater at the London Repeater Station.

The third Test Match was played at Leeds Cricket Ground and Score Recording Boards were displayed at Manchester, Blackpool,

Nottingham and Brighton. Manchester was once again included, but on this occasion the Board was displayed in the City Hall, Deansgate. Arrangements in this case were similar to those made in connection with the first Test Match, with the exception that a fourth Score Recording Board was available and was displayed at Brighton. On this occasion a fixed timed telephone call was given to Messrs. John Walker & Sons, Ltd. A normal call was passed from an extension of their Private Branch Exchange, connected to Royal Exchange, thence to the London Trunk Exchange, where the local junction was intercepted and connected to the main repeater network by way of the omnibus repeater. In this way, instructions were issued to their operators at the several Score Recording Boards, direct from Messrs. John Walker's offices at London. This was the first occasion on which the Department had operated two omnibus repeaters in series with one system of circuits.

The fourth Test Match was played at Manchester, and Score Recording Boards were displayed at Manchester, Blackpool, Nottingham and Brighton. Although the Score Recording Boards were displayed in the same towns as for the third Match, the Leeds circuit was no longer required and an additional local end to the Cricket Ground at Manchester necessitated the use of the omnibus repeater at Manchester Repeater Station. The circuit arrangements therefore again called for a system employing two omnibus repeaters.

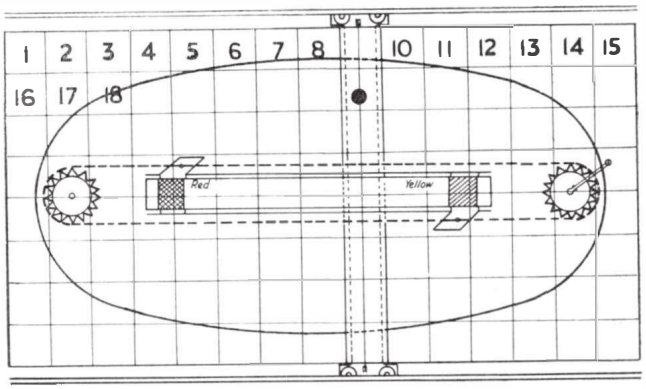
The fifth Test Match was played at the Oval, and boards were displayed at Brighton, Southend, Margate and Southsea. The omnibus repeater at London was used in this case and the Margate and Southsea circuits were teed together at the London Repeater Station.

The following details indicate briefly the construction of the Board, and the method of operating and recording the progress of the game. Fig. **2** is a photograph of the Score Recording Board at Brighton. Fig. **3** is a schematic diagram showing the mechanical arrangement of the Board. The Board is mechanically operated from information received telephonically, the operators having been previously specially trained in the work.

The batsmen are represented by two square coloured metal plates, one red and the other

Fig. 2.—Score Board at Brighton.

yellow. Projections from the backs of the plates pass through narrow parallel grooves in the "pitch," the projection on one plate being connected to the driving side and on the other plate to the following side of an endless bicycle chain, running on two chain wheels and rotated by hand. The respective batsmen are identified by corresponding coloured discs and pointers at the



Schematic diagram of Board.

Fig. 3.

bottom of the Board against their names and individual scores.

The ball is suspended on an endless wire passing through top and bottom guides which are fixed to a vertical lath located out of sight at the back of the panel representing the field of play. The endless wire is connected to a sliding handle on the lath. As the operator slides the handle up the lath, or down, the ball moves correspondingly, so that it is always at the same position on the front of the field of play as the handle is at the back. The lath is mounted on horizontal runner bars so that the whole ball control mechanism can move horizontally across the field of play. All working parts move freely on ball bearings so that the combination of vertical and horizontal ball movements will give diagonal or curved movements. The back of the field of play is divided into numbered squares. A telephonist at the Cricket Ground states the square to which the ball should be moved and all the operator has to do is to draw his handle in a direct line from the wicket to that square and the ball in front moves correspondingly. When a wicket fell, a flap with the word " out " in red letters dropped down and obscured the individual score of the batsman. At the same time, the way in which the wicket fell was indicated by replacing the blank panel against the particular cricketer's name by a panel marked " bowled," " caught," etc., the ball being left either at the fallen wicket or in the field at the position at which the catch was made. The bowler and the fielder were indicated by red pointers which were made to slide up and down on pulleys by the side of the players' names. The names of the batsmen who had completed their innings were shown in red with the scores opposite their names. The names of the players who had yet to bat were shown in black. A blank panel at the top right hand side of the board was used to indicate such information as " luncheon," " tea " and " rain stops play."

The operators were very proficient in working the mechanical devices and the play on the board was seldom more than one over behind the play on the cricket field.

The spectators applauded at the appropriate times and appeared to be as interested as they would be at the actual game. At a particularly brilliant piece of play or the batsman completing his 50 or 100 runs, " Johnnie Walker " on the top of the board raised his hat ! A special score recording card was used for each over to ensure correct operation of the Board. A copy of a typical card is shown in Fig. 4.

DATE_____ No. 197...

BALL	BOWLER END A	BATSMAN END	BYE WIDE NO BALL	REMARKS (WICKETS)	RUNS BAT	FIELDER	SQU	RET'D TO	TOTAL BAT	TOTAL EX	SIDE TOTAL
1	WALL	HOBBS			1	BRADMAN	13		13		59
2		SUTCLIFFE		BOUNDARY	4		20		45		63
3		"			–	KIPPAX	47		–		–
4		"		BOUNDARY	4		6		49		67
5		"			–	FAIRFAX	43		–		–
6		"			1	BRADMAN	14		50		68

SIDE TOTAL 68 | WICKETS DOWN – | RED BAT END 50 | YELLOW BAT. END 13 | TOTAL EXTRAS 5

Typical Recording Card.

FIG. 4.

Acknowledgements are due to Messrs. Paul E. Derrick, for permission to reproduce the photograph of the Score Recording Board and the Recording Card, and to The Sign Construction Co., Ltd., manufacturers of the Score Recording Board and the Sectional Engineer, Brighton South, who kindly supplied the information relative to the mechanical operations of the Board.

FIG. 5.—CROWD AT BRIGHTON WATCHING SCORE BOARD.

THE CENTRALISED TROUBLE SERVICE OF THE MUNICIPAL TELEPHONE SERVICE AT AMSTERDAM.

Dr. Ch. E. A. Maitland.

I.

THERE are several methods for the organization of the trouble service in a large telephone system with many exchanges.

(*a*) *Complete decentralisation.* Each exchange has its own trouble service. The subscribers have to lodge their complaints at the exchange to which their number is connected. Testing, administration and statistics are also concentrated at the Wire Chief's desk. The Troubleman is despatched from and reports to this desk. Each exchange has its own staff of Troublemen and works entirely independently of the others.

(*b*) *Partial centralisation.* The filing of the complaints, the administration and the statistics are centralised, and also the despatching of Troublemen. Testing and controlling are done at the Wire Chief's desk.

(*c*) *Complete centralisation.* All functions are centralised. The investigation and testing of reported faults is done on special test boards concentrated at one point for the whole system.

Until 1927 method (*b*) was followed at Amsterdam. Towards the end of that year system (*c*) was introduced and this system will be described below.

II.

First a couple of definitions. What is a trouble? What is the object of a trouble service? A trouble may be defined as a fault in the plant which is reported by a subscriber. There is also a group of faults found by the staff which may not have been reported by a subscriber. Some of them may have been observed by a subscriber, but when the latter does not report them these faults cannot be distinguished from the others and statistically cannot be recorded as troubles.

A distinction has to be drawn between the trouble service and the repair service. The purpose of the former is to clear the trouble as soon as possible. The object of the latter is to prevent complaints by detecting faults before they cause difficulties in the service. Both services are complementary to each other, not only technically but also economically.

When rapidity in clearing troubles is regarded as of prime importance economical use of the trouble staff is not possible. The number of complaints fluctuates widely and the staff being determined by the peak load would be idle during slack periods. Therefore, in order that no working time may be lost it is essential that the time for clearing troubles must be made a function of the number of complaints, or a buffer service must be organised to utilise the surplus of working time by decreasing trouble frequency. The maintenance and repair service can be organised to balance the fluctuations of the trouble service; it prevents faults and therefore complaints; it improves service and raises the reputation of the telephone system, and this is one of its most valuable assets.

In the exchanges where a fault may have considerable consequences and would be able to cause a series of complaints, it is obvious that maintenance takes first place. Prevention of faults is of the first importance and 80% to 90% of the faults will be found by routine testing.

The same methods cannot be applied in the outside plant, but although trouble service is of the first importance, prevention need not altogether be neglected.

In a modern telephone system equipped with well maintained automatic exchanges, the number of exchange troubles is negligible as compared with the normal amount of trouble in the external plant. Therefore, further improvement of the service must be sought in the reliable and speedy trouble service supported by a suitable maintenance and repair service. For this reason the new centralised trouble service was designed.

The functions of a complete trouble service may be described as follows:—

(1) Reception of complaints.

(2) Investigation of the fault, diagnosis of the case.

(3) Orders to trouble staff.
(4) Control of the work of the Troublemen and ensuring that the reported trouble is properly cleared.
(5) Statistics.
  (*a*) Per line.
  (*b*) Total, differentiated with respect to the description of fault.
  (*c*) Per man to judge of the efficiency of his work.
  (*d*) Statistics referring to the quality of the trouble service as a whole.
(6) Administration based on the results, orders for repair, maintenance or traffic investigation.
(7) General work to investigate the quality of service and regular preventive overhaul of the plant.

The organisation under the management of the Chief of the Trouble Service consists of the following parts :—

(*a*) Complaint receiving desk.
(*b*) Control Board.
(*c*) Statistical report desk.
(*d*) Administration.

These parts of the organization will be described below, showing how all the various functions are fulfilled.

All equipment has been manufactured and installed by Messrs. Siemens & Halske, Berlin.

III.—*The Complaints Receiving Desk.*

There is one desk for each unit of 10,000 lines. Fig. 1 shows this Board. It has two positions and three panels, the middle one containing a time-recording apparatus and an impulse register serving both sides. The side panels each take 20 lamps and jacks for incoming complaint calls. They are multipled to all boards and also on the control board.

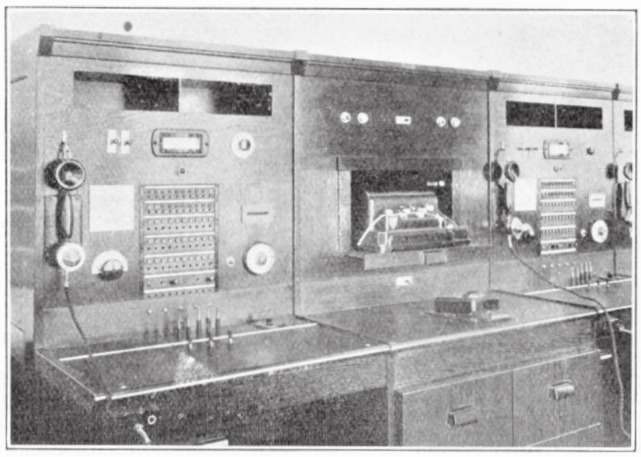


Fig. 1.—Complaints Receiving Desk.

The lamps associated with the 10,000 line unit to which the board belongs are white, all others are red. Normally only the white lamps are in operation, the red ones being connected to enable team work to be carried out during the peak hours.

Subscribers are requested to lodge complaints to the desk which attends to the number concerned in the complaint, but when they do not the call is extended on an order wire to its proper position where it is picked up in the multiple.

The installation is designed to permit of such concentration as may be necessary and the trouble control office may be attended to by as many officers as required. During night time the whole system is operated by one man sitting at the control board. Generally, however, complaints are dealt with on the desk to which the number belongs. At this desk each number has a card showing the name and address of the subscribers, the cable pair, the type of apparatus, extra contacts, switches, extension bells, etc. On this card is entered the date, time, character of complaint, time of clearing and nature of the fault. All those items are designated by a simple code so that they are filed according to a universal system. The cards may never be removed from their places unless they are wanted by the administration for alteration. In this event a dummy takes the place of the card removed, stating where the card has been taken to. The Trouble Officer has therefore all the cards at his disposal always. As soon as a complaint comes in he takes the card to verify the communications of the subscriber and at a glance has a brief summary of the history of the line, this being of great assistance in enabling him to judge of the character of the complaint. Investigation and testing are put in hand at once and this is one of the greatest advantages of the system.

The officer plugs up a test jack, of which there are two in each unit of 10,000. These test jacks are also multipled on all the boards for con-

centration. The test lines lead to test selectors, the contacts of which are connected with a special line switch in each 100's group. This final selector is also used in regular service, but is provided with a special device for testing (one extra relay). It is always connected to the 10th contact of the 3rd group selector, those being seldom busy.

The officer dials the subscriber's number and then he tests the outside and inside lines by means of a 16-point rotating switch, each position of which corresponds with a special testing device as shown in Table I.

TABLE I.

CONNECTIONS OF THE 16 POINT ROTATING SWITCH.

0	Zero.
1	Dialling the number.
2	Measuring Insulation Resistance A wire to earth.
3	,, ,, ,, B ,, ,, ,,
4	,, ,, ,, A to B wire.
5	Negative pole to the A wire.
6	,, ,, ,, ,, B ,,
7	Postive ,, ,, ,, A ,,
8	,, ,, ,, ,, B ,,
9	Testing of Subscriber's Condensers, charging.
10	,, ,, ,, ,, ,, discharging.
11	Speaking, calling, howler and dial test.
12	Same as 11 but A and B wire reversed.
13	Speaking through artificial cable, 2.5 neper.
14	Measuring resistance of the loop.
15	Testing Exchange side.
16	Same as 15 but A and B wire reversed.

After the investigation, the report is made on a slip of paper with all necessary particulars as to type of line, apparatus, cable pair, etc. This ticket is stamped with a time-recording apparatus and put on a carrier inside a row of boards on which it is transported to the Control Board. The card goes home, but is drawn out a little to the left so that one can see at once which cards belong to a number from which a complaint is current.

After the clearing of the fault the ticket comes back, the report is booked and the card restored to its place. This work is done by the same officers in slack periods.

On the cards all sorts of indices can be placed to mark special conditions, *e.g.*, line blocked, subscriber not in, construction work in progress on the line, line being overhauled by repair service or controlled by the Traffic office. On each Board there is also a test line to the M.D.F. which is multipled on all Boards.

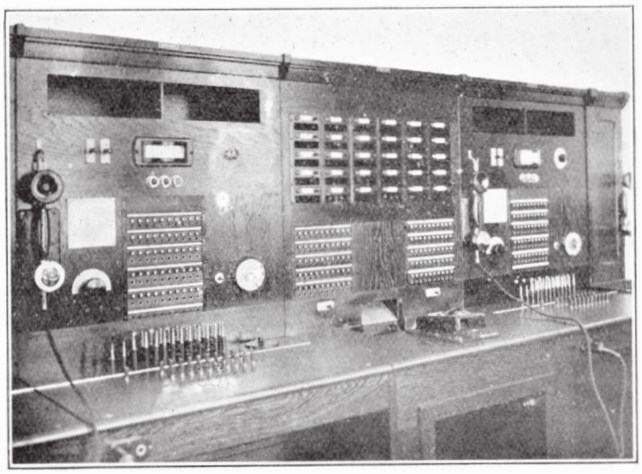


FIG. 2.—THE CONTROL BOARD.

IV.—*The Control Board.* (Fig. 2).

The officer on this board is responsible for sending out, directing and controlling the Troublemen. There are two boards, each with two positions. In the side panels there are 30 test jacks with busy lamps giving access to the test selectors. This is the multiple of the test lines on the receiving boards. Above, there are 20 lines for calls from the Troublemen. Below, there are 10 order wires for internal communications. On the key shelf there are two plugs and keys for answering and calling and 20 plugs and keys for direct test lines to the M.D.F. There are also a dial, a testing switch in accordance with Table I., an ohmmeter and keys for a howler and control lamps.

In the centre panel are situated the same calling lamps and jacks as appear on the receiving board, for use during concentration periods. There are also 20 test lines to the M.D.F., each equipped with an answering jack, a test jack and two calling lamps, one for incoming and the other for outgoing calls during testing. On the centre panel there is also mounted the output of the carrier, where tickets arrive, and in the lower part the impulse register stands on a slide. On the top of the centre panel there are a number of pigeon holes, each with a busy lamp and push button. The tickets for each of the Troublemen are stored in this compartment.

The working scheme is as follows:—

As each ticket arrives it is deposited in the pigeon hole of the Troublemen nearest to the

place where the faulty number is located, regard being paid to efficient distribution of work. As soon as each particular case comes to its turn, the address is given to the Troublemen who reports the clearing of the previous case and a test plug is inserted into a jack of a control test line to the M.D.F. where the number is jumpered. Here the test line is plugged to the required subscriber's line. This operation does not affect the subscriber's line, so that a subscriber is not disturbed if his line is in use. When the line is no longer busy, a cut-off key is pressed which disconnects the cable from the exchange line. The cable and exchange sides of the line are transferred to a calling lamp on the control board.

Calls from outside are answered on the control board and the calling party is informed that the line he asks for is faulty but is about to be repaired. On the cable side the Troubleman on duty reports as soon as he is on the spot, using a simple test box when the subscriber's apparatus is unfit for use. If the faulty line is still fit for use, the Troubleman rings up the Trouble office in the ordinary way, but on a number located on the control desk and only then is the cut-off key pushed, which disconnects the line.

The man at the control board first of all verifies the diagnosis of the receiving desk. He directs the Troubleman in his work, which is of great importance when the dial proves to be faulty or when poor transmission is reported. In the former case the impulse register is used and in the latter case an artificial standard cable with an attenuation of 2.5 neper. The most important task of the officer at the control board is to verify that the reported fault has really been cleared. The Troubleman is not discharged until this has been verified. The result is entered on the ticket which, after having been stamped by the clock, is sent to the Statistics Department, this being a desk placed at right angles to the control board. The effect of this method of controlling the Troubleman was evident from the decrease of repeat faults and from the decrease of the percentage of unfounded complaints from 50% to 30%.

The controlling officer has also a convenient opportunity to verify the condition of the whole of the subscriber's installation. Faults located in the exchange or in the cable plant are dealt with somewhat differently. It has been found that both those categories of faults only amount to about 20% of the total. Both kinds of troubles are reported to the exchange and to the cable repair service respectively. For them also, tickets are made out which are expedited to the Statistics Department where they are set aside until the clearing of the fault is reported by telephone. Faults detected in P.B.X. installations, which have to be dealt with by the P.B.X. Department, are handled in the same way. Most of these complaints, however, reach the P.B.X. Department at once.

The control of the Troublemen is carried out as follows:—

As soon as the man arrives on the spot and starts to work, the button near his pigeon hole is pushed. This lights the lamp so that it is

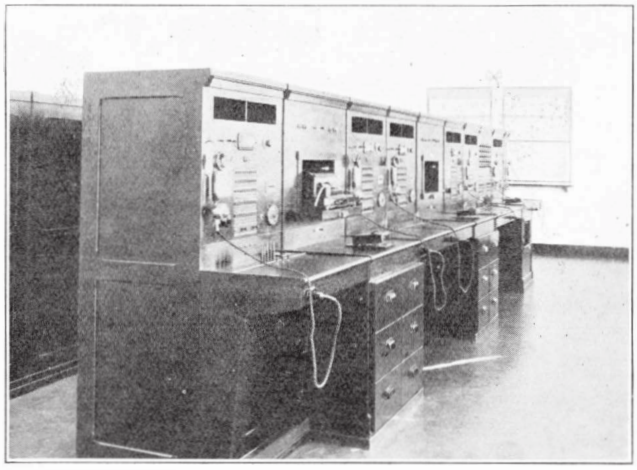


FIG. 3.—ROW OF BOARDS IN CENTRAL TROUBLE OFFICE.

immediately apparent which Troublemen are on the job; secondly, a counter is worked which gives the number of cases handled; and thirdly, a time meter is put in action which afterwards shows the time taken to clear the fault. For each man, therefore, it is possible to know how many cases he has handled, his working time and also, by simple subtraction, the time occupied by travelling from one place to another. His total time on duty is registered at the control board. As soon as a man is superfluous he is shifted over to the repair service for overhaul work. Fig. 3 shows the row of boards consisting of two receiving desks and a control board. There are

two of such rows at the Trouble Central Office at Amsterdam.

V.—*The Statistical Department.*

At this table, shown in Fig. 4, all tickets issued arrive; not only those referring to troubles cleared either by the Trouble service or by another department, but also those referring to complaints on which no fault could be found. When the service is closed down at night, this desk must have issued all the tickets. This is always verified to ensure that no tickets are missing.

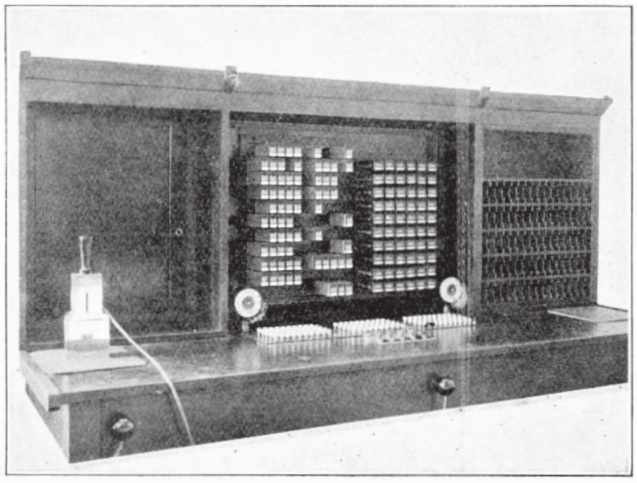


FIG. 4.—THE STATISTOGRAPH.

On the statistical report desk are concentrated all the meters. These include the counters referred to above for controlling the working time and two groups of counters worked by a key board in the shelf. One of them registers the effect of the service and the other produces the statistical records regarding the character of faults. The effect of the service is measured by the time which elapses between the filing of the complaint and the clearing of the fault. This is done in two ways, once by taking the difference between the two time stamps, and again by deducting the time during which service has been suspended. The first item gives the time the subscriber has waited for the removal of the fault, the second gives the time taken by the service to clear the trouble. In Table II. the result of these statistics is reproduced for the year 1929.

TABLE II.

STATISTICS ON THE DURATION OF FAULTS.

	Subscriber's time.	Service time.
	%	%
Less that ½ hour	20.80	26.80
½ — 1 hour	26.90	27.50
1 — 2 ,,	21.70	24.20
2 — 3 ,,	12.50	14.20
3 — 6 ,,	2.95	5.50
6 — 12 ,,	2.96	6.50
12 — 24 ,,	10.30	0.95
More than 24 hours	1.98	0.35
	100.00	100.00

The statistics showing the character of the faults are derived from the code indications on the tickets, each of them having a number represented on the key board. Complaints and faults are divided into groups which are subdivided into smaller groups and finally reassembled into larger groups. All this work is done automatically by routing the meter current from the keys in a special way. For this purpose meters and key contacts are connected in series and parallel, which can be done on an intermediate distributing frame so that the grouping may be altered as circumstances require. At any moment the statistics can be detailed as much as necessary and as long as useful without difficulty and without incurring more work. This counting apparatus, Statistograph, does automatically all the statistical work, divides into groups, combines again, totalises, gives daily and monthly records and controls itself. Statistics cost no more time than is wanted to read the tickets and to push a button; the Chief has all his data and records daily by reading the counters and another set of counters gives the monthly records.

VI.—*The Administration.*

All tickets finished at the Statistical report desk go back to the Receiving desk *via* the Administration. Here a record is kept of all complaints on which no fault could be detected. When the same number appears three times within a period of a month, an order is given to the Repair service for a thorough overhaul. When the number appears again, it is reported to the Traffic office for permanent observation.

The Administration further assembles the statistics, keeps the card system up to date, places indices on the cards for all purposes and controls the complete circuit of the tickets. When the ticket returns to the Receiving desk the card is put in its place after the report has been noted.

Finally, a few remarks about the systematic overhaul. Every Troubleman not wanted for clearing faults is transferred to the Repair service and used for overhaul of plant. Besides the overhaul of numbers with an abnormal trouble frequency, as mentioned above, there is also a systematic revision of the whole plant in order to prevent complaints and to inspect the installation at the subscriber's premises. In slack periods the Receiving desk arranges for numbers to be tested systematically and reports all defects to the repair service.

The advantages of the methods described above can be summarised as follows:—

With a smaller staff than previously, it has been found possible to organise a highly efficient and rapid Trouble service, open practically all day, *i.e.*, from 8 a.m. to 11 p.m. on week days and from 9 a.m. to 5 p.m. on Sundays. The time taken to clear the fault is short, being on the average 2.061 hours in service time and 3.587 hours in subscriber's time; 47% of the faults are cleared within one hour. Investigation of the fault commences as soon as the complaint is made and this makes a good impression on the public, which sees that attention is being given at once.

It is also important that in many cases it is possible to investigate the complaint at the moment it arises, particularly with intermittent troubles. As a trouble card is at hand for each number, diagnosis is facilitated and exaggerated complaints by the subscriber can be exposed at once.

Another feature of great importance is the control of the Troubleman, who is not released before he has really cleared the fault. As the time the Troubleman takes for his work and to travel from one place to the other is recorded no time can be wasted. The statistical report gives the Chief a daily survey of the results obtained.

The systematic preventive inspection or overhaul of the plant prevents faults, keeps up a highly efficient service, fully employs the spare time of the staff and affords a rapidly working Trouble service even at peak load without any waste of time in slack periods. With the inspection and overhaul, the administrative data of the installation at the subscriber's premises are kept under review at the same time and this is very useful.

In order that all numbers shall be overhauled within a reasonable time a small permanent staff is wanted for the overhaul service.

To realise the scheme described above, it is necessary to have a staff of two officers at the Receiving Desk, one at the Control, six to seven Troublemen and two men for permanent revision service per 10,000 lines. For the Administration one man is required per 20,000 lines. With this staff 15,000 troubles and 3,000 revisions can be handled per annum. As stated above, the P.B.X. service is not included.

DEVELOPMENT IN P.A.B.X. DESIGN.

B. F. Moss,
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THE primary purpose of this article is to give a description of a recent development in the design of Private Automatic Branch Exchange systems.

In order, however, that the merits of the new system may be clearly appreciated, some attention will be paid to the operation of existing systems with a view to reaching conclusions as to their respective advantages and disadvantages. From these considerations it should be possible to obtain an impression of the requirements of an ideal system. The system to be described is the result of attempts to meet these requirements.

In order, also, that the system may be readily understood, the line of thought which influenced the design of each section of it will be closely followed. The reasons underlying the design of these sections will be discussed before the system, as a complete unit, is described.

A P.A.B.X. may be described as a private automatic exchange which has connection to the local main exchange. As the exchange is private, the numbers of the extensions on it will not be generally known to main exchange subscribers and hence it is necessary that incoming calls to the P.A.B.X. are intercepted by an operator, who is in a position to extend the calls to the correct extension.

It is not the purpose of this paper to discuss the automatic switching plant in P.A.B.X's. This plant is generally based on well proved main exchange practice which has, for the present, reached a certain degree of finality. The intention is to consider that portion of a P.A.B.X. which is concerned with providing communication with the main exchange, for it is in this direction that the recent development in design has been applied.

In so far as the method by which they provide connection with the main exchange is concerned, the existing types of P.A.B.X. systems may be divided into two classes. In both these types of P.A.B.X's calls incoming from the main exchange are extended in the same manner. For the reasons already stated these calls are intercepted by the local operator, who extends them to the required extension lines. It is in the method of switching outgoing calls in which these classes of systems differ.

In one class of system all outgoing calls are controlled by the local operator. On the receipt of a call from an extension, the operator completes the connection, with her cord circuit, to the junctions to the main exchange. If the main exchange is automatic, and it will be assumed that this is the case wherever main exchanges are discussed, the operator has to dial the number of the wanted subscriber.

In the other class of system each extension obtains connection with the main exchange automatically after the dialling of a pre-determined prefix digit, and without any intervention by the local operator.

Each of these systems has certain inherent advantages and disadvantages. The first mentioned type, that in which all calls are controlled by the operator, has the disadvantage that the services of the operator are required for the complete setting up and releasing of each outgoing call. That is to say, the operator has to manipulate cords and plugs, effect the necessary dialling, and then generally supervise the call in order to release the connection on receipt of the clear signal. It is proposed to criticise these points individually.

Firstly, the manipulation of cords and plugs gives rise to a chance of incorrect operation, particularly when it is remembered that a P.A.B.X. operator is not, as a rule, as efficient as a public exchange operator. Secondly, the dialling by the operator naturally occupies an appreciable amount of time, particularly as the main exchange may be in a Director or other type of multi-exchange area, when up to seven trains of impulses have to be dialled. In addition, as very often the actual number required will be repeated by word of mouth by the extension to the local operator, misunderstandings may often arise and wrong numbers be connected.

Finally, the fact that the operator has control of the release of the connection has a bearing on the amount of traffic which can be carried by the junction lines. On these outgoing calls the junction is held busy as long as the operator leaves a cord circuit connected to a junction. Therefore to utilise the junction as efficiently as possible each connection should be taken down as soon as the clear signal is given. Although a well trained operator might not lose much time in responding to clearing signals, she naturally, and quite correctly, gives attention to calling signals in preference to clearing signals. Therefore, it is quite probable that on every outgoing call a certain amount of time may be lost before the connection is released after the clearing signal is given. Although this amount may be small, where exchange lines are concerned every second lost unnecessarily has its effect on the traffic efficiency and therefore the economic value of these lines.

There is one definite advantage that is obtained from this particular type of system. As the operator has control over all outgoing calls, she can use her discretion in deciding whether the originating call is one that should be extended to the main exchange. In many cases the calling extension may not know the number of the wanted subscriber. If this should be the case the extension communicates the name of the subscriber to the operator who, from a public directory, is able to ascertain the required number. If, however, the extension is provided with facility for reaching the main exchange direct he would be tempted very often to request this, or any other, information from the main exchange operators, who might therefore be troubled very often and quite unnecessarily from these enquiry calls. It is quite probable that a 50 line P.A.B.X. having, say, five exchange lines and in which all extensions can dial out direct, may easily create enquiry calls to the main operators far out of proportion to the number of exchange lines in use.

It should be mentioned that on systems of this type facilities are always provided whereby extensions can call their local operator and, if necessary, be connected by her to the main exchange. This fact, however, does not influence the argument that has been propounded.

The type of system which provides extensions with direct dialling facility to the main exchange has the advantage that the local operator is relieved of all work in connection with outgoing calls and she can therefore concentrate on the control of incoming calls. Each operator is able to attend to a larger number of these calls and therefore fewer operators would be required for a P.A.B.X. of given size with a given junction traffic. This type of system has, however, the disadvantage, already discussed, that it allows possibility of the main exchange operator being unnecessarily troubled.

From this discussion on the merits of the existing systems it should now be possible to define the requirements that would be demanded from an " ideal " system.

Obviously an ideal P.A.B.X. system would be one that incorporates the advantages of each of the systems already discussed, with the disadvantages of neither. As the chief advantage of one system is that the operator controls the outgoing calls and of the other that the operator does not have to concern herself with these calls, the ideal system would be one in which the operator controls all these calls without spending any time on them. This is obviously impossible; the nearest that can be reached to this ideal is a system in which the operator controls all outgoing calls but spends as little time as possible on each.

In order to build up the system which is to be as near as possible to the ideal, it will be necessary then to take as a basis the system in which the operator has full control of outgoing calls, and attempt to reduce the time she spends on each call.

Now it has been stated that it is a disadvantage if the operator dials out, but no disadvantage if the extensions dial out. Therefore in the new system it should be arranged that the operator connects a calling extension through to the junctions and it should then be possible for the extension to dial through the cord circuit. This requirement is easily met by arranging the cord circuit to include an impulse repeater operating on standard principles, whereby the impulse dialled out by the calling extension and received by this repeater would be repeated over the junctions to the main exchange. It will not prove difficult to arrange, in the same cord circuit, that the operator is able to dial out should

the calling extension be unaware of the number required.

The arrangement decided upon then is that the operator controls all outward calls, but does not necessarily have to effect the dialling for each call. This will economise on the amount of time the operator spends on each call. To reduce this time still further, however, it is necessary to pay attention to the other points that have been mentioned as disadvantages of this system. It was mentioned that the operator has to resort to the use of plugs and cords with consequent risk of wrong connections and that she has to supervise the call and take down the cords as quickly as possible at its termination. These points bear a relationship to each other and may be considered together.

It is an advantage, it has been argued, if the operator controls the setting up of outward calls. Her services afterwards, now that it is arranged for the extension to dial out, will only be required for taking down the cords when the call is finished. In fact, if there were no cords to be taken down, the operator's services would not be required beyond the connecting through of the call to a free junction line. In order to determine whether, on these outgoing calls, the cords may be eliminated, it is necessary to consider the functions the operator normally performs with them and ascertain if, and to what extent, these functions may be performed by automatic apparatus.

The answering cord is used by the operator for connecting a calling extension line to a cord circuit. This action may be defined as consisting in the operator connecting an idle cord circuit to a particular calling line. This sequence of operations, however, is analogous to that which occurs on most of the small automatic exchanges operating on the line-finder principle. On exchanges of this type each first selector has directly connected to it a line-finder switch of rotary type. By the use of assignment switches the selectors are assigned to function in rotation.

It may be said that the action of the operator in choosing a free cord circuit is the same as that of an assignment switch. When the operator plugs into the particular calling jack she does no more than a line-finder switch when it makes connection with the calling line. The action in both cases provides the same result. Thus these actions of the operator have a direct simile in a line-finder system. Hence it should be feasible to effect, by automatic means, this operation of answering a calling extension.

Each cord circuit then, on its answering side should have its answering plug and cord replaced by a rotary line-switch, which may be termed the extension finder, operating as a line-finder. In order that the free cord circuits may be correctly assigned a pre-assignment switch, which may be common to a number of cord circuits, will be required. So that they may be distinguished more easily it is proposed that the cord circuits of the new system be termed "Auto-Cord Circuits."

The sequence of operations now arrived at will consist in the extension dialling "●" and the extension finder switch associated with an idle auto-cord circuit, will then hunt for and make connection with, the calling line. In order to give a calling signal a lamp should glow on the manual board. This lamp should be in close proximity to other apparatus, individual to each auto-cord circuit, which it may be found necessary to mount on the manual board. A Speaking Key will enable the operator to speak to the calling extension.

The case to be considered now is that of the operator extending a call to the main exchange junction lines. This normally is effected by the operator plugging into a free junction jack with the calling plug of the particular cord circuit in use. This operation can be said to consist in the operator causing a certain cord circuit to make connection with any free junction line. This sequence of connections is also analogous to those in use in automatic switching practice and it can be performed automatically on either the line-finder or preselector principle. In order to concentrate as much apparatus as possible in the auto-cord circuit it proves preferable if the preselector principle is employed. That is, a rotary line switch is connected to each auto-link circuit and, under certain conditions, will hunt for and make connection with, a free junction line. It is necessary that this switch action is controlled by the operator, as not every call will require extending to the main exchange. Hence a key is required to set the switch, which may be termed the Junction Finder, into operation. This Junction Connect key should be restored

when a junction is seized and dial tone is heard.

As a repeating element is to be included in the auto-cord circuit, the extension may now dial the required number and the operator need have no further interest in this call, provided her services are not required for any releasing purposes. It is quite feasible, however, to provide automatic release because, as the circuit has been set up automatically, it should be possible to release it in the same manner. The action then of the calling extension replacing his receiver should disconnect the junction and restore the auto-cord circuit to normal.

The results achieved by the auto-cord circuit effectively overcome the disadvantages that have been said to exist if the operator extends outgoing calls. The operator's total work on the majority of these calls will consist in throwing one key to speak to the caller and then throwing another key momentarily to connect to a junction, thereafter her services are not required. The risk of the operator making wrong connections is eliminated, as plugs and cords have been deleted, and the risk of the operator misunderstanding the number wanted is eliminated by allowing the extension to dial for himself. Finally, as the junction and cord circuit are released automatically immediately the extension hangs up, the fullest possible efficiency is made of them for traffic carrying purposes.

Having increased the efficiency in operating outgoing calls by the introduction of automatic switching principles, it may be possible to improve the operating of incoming calls in the same manner. Consideration therefore should now be given to the operation of incoming calls.

In normal practice each junction terminates in a jack and lamp equipment on the manual board. The operator answers a junction call by plugging into the jack associated with the calling lamp and extends the call by plugging into the jack associated with the line of the wanted extension. When the operator answers the call she causes a particular junction to be connected to a free cord circuit. This is analogous to the case, already discussed, of connecting a particular extension to a free cord circuit and can be completed automatically. A Junction Finder switch is already required for each auto-cord for use on outgoing calls. By suitable circuit arrangement it should be possible to utilize this same switch and cause it to act as a line-finder on incoming junction calls.

The advantage gained by making this operation of answering incoming calls automatic are two-fold. Firstly, the answering plug has been entirely dispensed with, as all answering actions can now be performed by automatic means. Secondly, the manual board apparatus associated with the junction lines, such as lamp and jacks, can be deleted as all connections between junctions and auto-cord circuits are completed automatically.

The final function of the operator to be discussed is that of extending an incoming junction call to the wanted extension. This is generally effected by the operator obtaining direct connection by cord and plug. This connection could be completed by the operator dialling the number of the wanted extension, but this method is not efficient as the operator would have to spend time in dialling and also each call would then occupy a train of switches in the P.A.B.X. Hence the arrangement would be slow and expensive. Therefore it does not appear that the existing method can be improved upon, particularly as it is quick in operation and has, in fact, no outstanding disadvantages.

On incoming calls then, the calling junction will be automatically connected to a free auto-cord circuit and the operator will then plug into the jack associated with the required extension line. Each auto-cord circuit will thus have connected to it a plug and cord for this type of call. In order to simplify operating arrangements it should not be difficult to ensure that when, on receipt of the clearing signal, the operator withdraws the plug, the auto-cord circuit is restored to normal.

Sufficient data has now been obtained for the auto-cord circuit to make it possible to draw up a schematic trunking diagram of a P.A.B.X. embodying this circuit and, from it, to give a brief description of the operations occurring on outward and inward calls. Fig. 1 illustrates the main elements of the P.A.B.X.

When an extension lifts his receiver and dials " O," relays in the auto-cord circuit, which has already been assigned by the assignment switch, are operated and cause the Extension Finder switch to hunt for the calling line. As soon as the auto-cord circuit is seized, the assignment

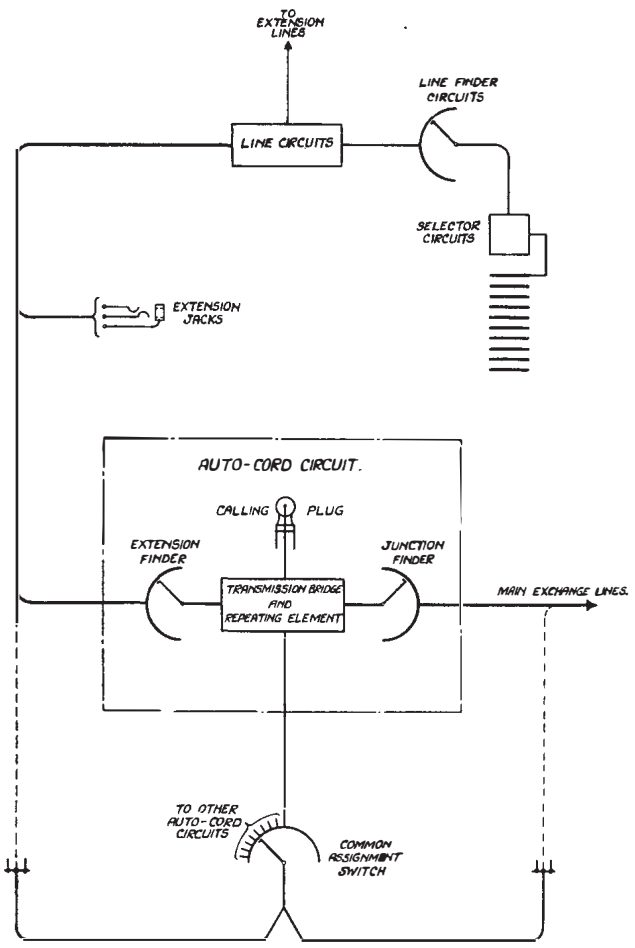


FIG. 1.—TRUNKING SCHEME OF AUTO-CORD TYPE P.A.B.X.

switch operates automatically to assign the next free circuit. A calling lamp glows to give the necessary signal. The automatic switches, comprising line-finder and selector, taken into use by the extension in dialling "O," are released as soon as the auto-cord circuit is connected through its extension finder to the calling line.

The operator throws the respective speaking key and speaks to the calling line. If the latter requires connection to the main exchange and wishes to dial himself, the operator throws the Connect Key. This causes the Junction Finder to hunt for a free junction line. The operator holds the Connect Key thrown until she hears dial tone, indicating that a first selector has been taken into use at the main exchange. The operator informs the caller when to dial and then restores both keys. The extension's dialling impulses are received in the auto-cord circuit and repeated out over the junction.

The action of the caller hanging up releases all relays in the auto-cord circuit and therefore disconnects the holding loop to the main exchange, the auto switches at the main thereupon release to normal. The auto-cord circuit is now available for use on other calls.

On incoming junction calls a cord circuit is seized in just the same manner as on outgoing extension calls. The same assignment switch can be employed for both types of calls. Hence on receipt of an incoming call, relays are operated in the particular auto-cord circuit which is seized and cause the Junction Finder switch associated with it to hunt for the calling junction. A Junction Calling Lamp indicates to the operator the type of caller. On noticing this lamp the operator throws the Speaking Key connected to the auto-cord circuit, and speaks to the caller.

The operator now plugs into the jack of the wanted line with the plug associated with the auto-cord circuit. She then rings out in normal manner by throwing a Ringing Key. Supervision from the called extension is given on a third, supervisory, lamp.

On receipt of the clearing signal, given by the supervisory lamp, the operator withdraws the plug. This action automatically releases the auto-cord relays and renders the circuit free to be seized by other calls.

It has been mentioned that three lamps are required on each auto-cord circuit, two lamps being employed as respective calling signals from extensions and junctions. The third lamp is used to give the clearing signal on incoming calls. In order that the operator may be able to note the quantity of circuits in use at any one moment a fourth lamp, the Engaged Lamp, is employed. This lamp is not normally in use, but should the operator wish to originate a call herself she presses a certain common key. This causes the engaged lamps to glow on all busy circuits. The operator can therefore at any time ascertain which circuits are free and take one into use if she wishes.

It might appear that considerable complication of the extension line circuits is necessary to enable the extension finders to search for calling extensions. Actually this arrangement is made possible by the addition of a non-inductive resistance to each line circuit and no additional con-

tacts or other apparatus are necessary. This point is of considerable importance, as the cost of each line circuit has naturally an important effect on the total cost of an exchange.

In order to illustrate easily the various apparatus fitted on a manual board equipped with auto-cord circuits, a diagrammic view is given in Fig. **2** of a board serving an 80 line P.A.B.X.

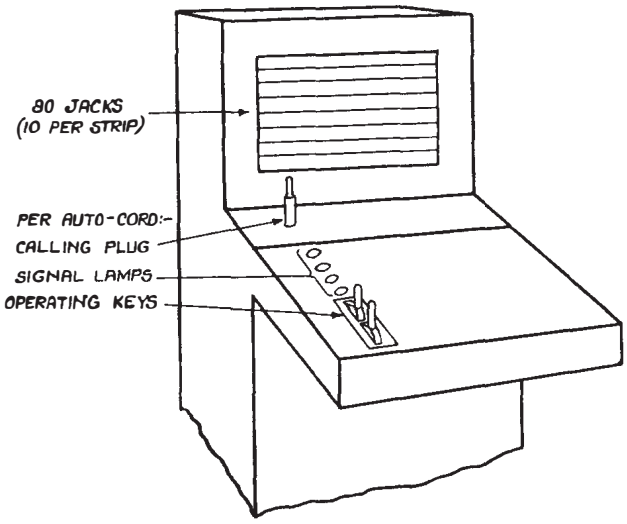


FIG. 2.—80-LINE AUTO-CORD TYPE SWITCHBOARD.

Each auto-cord circuit is shown to have a plug, four lamps and two keys. One lamp, the Engaged Lamp, is very rarely employed and for ordinary operation the operator has only to concern herself with the three lamps. Apart from the auto-cord circuit apparatus the only other apparatus fitted on the board are the 80 extension jacks.

It should now be possible to discuss the auto-cord system on the question of economics and compare it, on this basis, with existing systems. As the existing system which the auto-cord system more closely resembles is that with direct dialling-out facility, it is with this that comparison will be made.

Fig. **3** illustrates, diagrammatically, the equipment required on a manual board, serving an 80 line P.A.B.X. of the direct dialling-out type. In comparing Fig. **2** with Fig. **3** it may be noted that the equipment mounted on the vertical panel of the manual board actually occupies 175% more space in Fig. **3** than in Fig. **2**. This fact alone facilitates the use of a manual board of especially simple construction wherever the auto-cord system is employed. In addition, much of the apparatus in the auto-cord circuits is concentrated, as far as wiring connections are concerned. Thus it can all be mounted on a frame work separated from the manual board and comparatively few wiring connections between rack and switchboard will then be required. Hence, there is no apparatus, such as relays, that need be mounted on the switchboard, thus further simplifying this portion of the exchange.

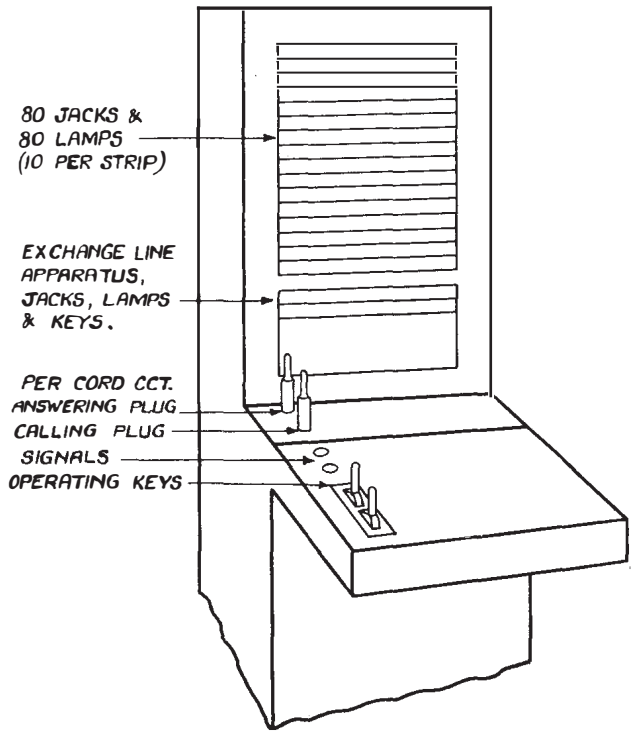


FIG. 3.—80-LINE STANDARD TYPE SWITCHBOARD.

In practice, the boards shown in Figs. **2** and **3** are equipped with certain miscellaneous apparatus which, as they are not the concern of this article, have been deleted. For the sake of comparison both boards are shown to have one panel only. This would not necessarily be the case in practice.

In Fig. **4** a detailed comparison of apparatus quantities is given between two 80-line P.A.B.X. systems, one operating on the direct dialling-out basis, the other on the auto-cord scheme. It is assumed that both exchanges have the same traffic rate.

FIG. 4.

COMPARISON OF APPARATUS FOR 80-LINE P.A.B.X.

	Standard P.A.B.X. System.	Auto-Cord System.
AUTO-SWITCH PLANT.		
Line Circuits	80	80
Selector Circuits	12	9
MANUAL BOARD APPARATUS.		
Extension Jacks	80	80
,, Calling Lamps	80	Nil
Junction Lines	7	6
Exchange Lines Jacks, Lamps and Keys	7	Nil
Exchange Repeater Circuits	7	Nil
Cord Circuits	8	7
Cords and Plugs per Cord Circuit ...	2	1
Keys ,, ,, ,, ...	2	2
Signals ,, ,, ,, ...	2	4

It will be noted that a reduction of three circuits is made in the selector circuits. This is made possible by the fact that the selectors do not carry any main exchange traffic and are only held in use momentarily on calls to the P.A.B.X. operator. On the standard system, however, the selectors carry all outgoing traffic and therefore sufficient switches must be provided to carry this, and the internal, traffic.

It will also be noted that six junction lines are quoted for the auto-cord system against seven for the standard system, although it was stated that the traffic rate of each exchange is the same. This difference is explained by two facts. Firstly, in the auto-cord system each junction call is completed and released, at the termination of the call, with the minimum of time lost. Each junction therefore is operated at a higher rate of efficiency and thus can carry a higher traffic rate than the junctions on the standard P.A.B.X. Secondly, all junction calls on the auto-cord system are intercepted by the P.A.B.X. operator, and, for reasons already discussed, fewer enquiry calls will therefore be carried by the junction lines.

Another point to note in Fig. 4 is that seven cord circuits are quoted for the auto-cord system against eight for the standard system. These figures require a little explanation.

Taking, firstly, the case of seven auto-cord circuits, it has been stated that the number of junction lines required for the auto-cord system is six. Hence the maximum number of conversations that can take place over these junctions is also six. To establish these connections a similar number of cord circuits is required. Therefore to carry the junction traffic six cord circuits are required; to enable the operator to deal with enquiry calls when the junction traffic is at peak load, a seventh circuit should be provided.

As, on the standard system, outgoing calls are dialled direct, it might be argued that eight cord circuits are unnecessary for seven exchange lines, for it may appear that these cord circuits have only to carry incoming traffic. On this type of exchange, however, extensions always can, if they wish, be connected to the main exchange by the P.A.B.X. operator. Therefore, sufficient cord circuits must always be provided to carry, besides the peak incoming traffic, certain of these outgoing calls and still have at least one circuit for enquiry calls.

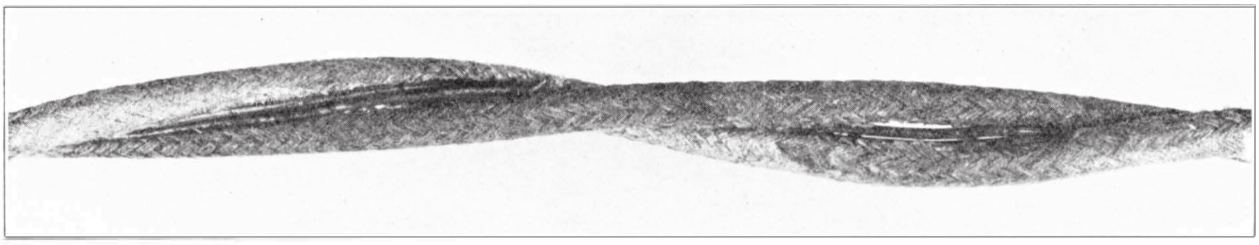
A point then that can be raised against the direct dialling-out system is that although, as has already been mentioned, sufficient selectors must be provided to carry the peak outgoing traffic, the number of cord circuits must be sufficient to carry some outgoing calls. It is clear then that at any given moment a certain number of either the selectors or the cord circuits must always be idle.

The figures given in Fig. 4 refer to exchanges having a certain traffic rate, of an average value. If, as may be quite possible, a particular 80-line exchange has a higher traffic rate than in the examples given, the difference in quantity of apparatus required for the two types of systems will naturally be more marked.

From a consideration of known types of P.A.B.X. systems one is lead to believe that the manual board equipment has merited more development than it has received. By applying automatic switching principles to this manual board equipment and rendering automatic many operations which have hitherto been considered of a purely manual nature, it is suggested that a more efficient system has been developed.

PECULIAR LIGHTNING EFFECTS.

READERS of the Journal will be interested in the following account of the peculiar effects of a lightning stroke which have been communicated to Sir Thomas Purves by Mr. H. P. Brown, Secretary of the Postmaster-General's Department, Commonwealth of Australia. The telephone line concerned was a subscriber's circuit, metallic throughout, and consisted of 50 yards of 10 lb. conductor P.C. cable, and 3.6 miles of 40 lb. cadmium-copper wire. About half a mile from the subscriber's premises, the circuit left the main line at a cross-armed pole. The cross connections were made with insulated wire, and this wire was found in six pieces. The insulation was not damaged, but it was possible to draw the end pieces of the wire freely from the insulation. The circuit was led in to the subscriber's premises by means of a twisted pair V.I.R. insulated cable 90 feet in length. The second pole from the subscriber's premises was struck, and a chip 9″ long, ½″ wide and ¼″ deep was taken off the sap wood at the tip of the pole. The copper cadmium wires were burnt through in two spans between the terminal and the junction poles. This is, of course, quite a normal occurrence in such cases, but the peculiar effect which it is desired to bring to notice concerns the twin insulated leading-in wire between the terminal pole and an insulator which secured the wire to the building. This wire was not burnt or charred in any way, but the black insulated conductor was completely removed from its insulation as though the latter had been slit spirally along the lay with a knife, and forced into intimate contact with the red insulation of the other conductor. The red insulation was not cut through so completely as the black, but close inspection revealed the fact that the fibres were damaged, since it was easy to tear the insulation longitudinally. In some parts, both wires were actually found inside the red insulation.



PHOTOGRAPH SHOWING CONDUCTORS BETWEEN BRAIDINGS.

The fuses in the subscriber's premises are said to have operated and there were marks of a heavy discharge on the lightning protectors. The heat coils did not operate. At the exchange, the

fuses operated, but it cannot be stated definitely that there were any signs of the protectors having discharged.

It is reported that there was a lighted kerosene lamp on a table about four feet from the telephone, and that although this was extinguished, it was not damaged in any way.

It is not very easy to provide a satisfactory explanation for this phenomenon. The damaged cable has been examined microscopically and the opening along the rubber appears to be a perfectly clean mechanical cut. The indiarubber does not appear to have been affected by any appreciable rise in the temperature of the conductor, and there are no signs of burning on the braiding. It would, therefore, appear that the explanation is that the occurrence was due to an intense mechanical attraction between the two conductors when each was momentarily carrying a heavy current in the same direction. A rough test on the force required to cause one of the conductors to cut through the rubber and the braiding in this way has enabled a calculation to be made which shows that, to produce the effect, each wire must have carried an instantaneous current of the order of 15,000 amperes!

An article has appeared recently in a contemporary journal which describes this occurrence, and advances the theory that "the passage of a momentary strong discharge intensely heated the surface of the wire so that the air or any other gases evolved were expanded with sudden violence, and consequently with explosive effect." It is difficult to understand how this effect could result in placing both conductors in the one braiding, it would seem that such an action would rather tend to separate the conductors.

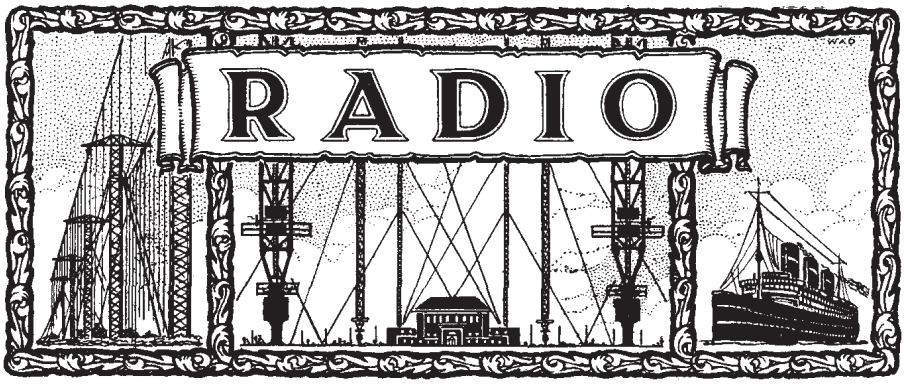
It is somewhat difficult to obtain a photograph of the damaged cable which will show the two conductors in the one braiding. The accompanying illustration, however, shows a representative length. At one end, both wires are clearly shown free of their insulation, whilst at the other end, one conductor is still covered.

H.C.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH JUNE, 1930.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileage.				Engineering District.	Underground Wire Mileage.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
684,086	529	3,964	53,684	130	London.	25,123	89,040	2,595,358	85,800
90,838	2,182	21,502	70,886	2,165	S. Eastern.	4,043	63,778	258,864	34,661
94,108	4,482	32,023	66,184	3,951	S. Western.	21,954	17,861	200,627	63,762
75,996	6,332	39,335	69,924	6,456	Eastern.	24,699	47,965	160,401	62,513
107,996	9,661	45,252	65,990	4,761	N. Mid.	33,130	63,469	281,487	103,393
94,036	4,828	31,329	80,833	4,168	S. Mid.	13,881	31,466	226,050	78,771
63,191	4,576	30,140	58,743	3,503	S. Wales.	6,645	30,920	140,675	68,399
118,098	7,966	27,045	55,828	4,130	N. Wales.	13,831	43,462	318,966	52,951
173,464	1,469	16,049	45,459	3,092	S. Lancs.	14,561	89,996	546,484	61,698
101,723	6,083	30,770	50,428	3,251	N. Eastern.	14,062	51,042	281,137	72,498
69,690	3,907	24,122	41,114	2,717	N. Western.	7,753	37,277	180,587	43,310
52,579	2,494	15,903	27,497	3,253	Northern.	7,597	22,155	146,862	37,919
24,126	4,427	8,944	14,721	632	Ireland N.	135	3,160	51,923	2,407
72,893	4,815	27,381	42,279	1,319	Scotland E.	6,474	17,929	168,770	40,098
95,433	7,247	24,722	46,160	1,283	Scotland W.	11,475	29,793	240,094	32,950
1,918,248	70,998	378,481	789,730	44,811	Total	205,363	639,313	5,798,285	841,130
1,892,658	70,576	377,284	775,678	44,508	Figures as at 31 Mar., 1930.	203,138	622,970	5,678,546	839,746



RADIO DIRECTION FINDING AT POST OFFICE COAST STATIONS.

G. H. Farnes and F. Hollinghurst.

DURING conditions such as obtain in fog or stormy weather with low visibility, when it is not practicable to obtain astronomical bearings or visual bearings on landmarks when approaching a coast, navigators of ships feel the need of some means of checking the ship's position as determined by the very approximate method of " dead reckoning."

In order to fix accurately the position of a ship three bearings on different fixed points are necessary; these bearings when laid out on the chart give the well-known " Cocked Hat." Two bearings on fixed points will, however, enable a ship's position to be determined with fair accuracy, and even one accurate bearing from a position suitably situated with regard to a harbour or estuary will be of considerable use to a ship during poor visibility conditions.

There are several methods whereby radio systems can be utilized to fill this need, and after careful examination of the problem it was decided in 1921 to investigate the possibility of utilizing the existing coast stations of the British Post Office and the corresponding ships' installations for this service. Under this method no special apparatus would be required on ships, the bearing of a ship being taken at a coast station by special receivers at that station utilizing the signal from the ordinary ship's transmitting set.

Although the situations of the Coast Stations then in existence were not ideal for the purpose, the cost of apparatus necessary for direction-finding at an existing station is very small compared with the cost of equipping and running a complete station solely for direction-finding purposes. The ideal system would, of course, be a chain of stations erected simply for direction-finding purposes, but the cost of such a scheme would be prohibitive.

Niton Wireless Station in the Isle of Wight was accordingly equipped with directional receiving apparatus. The system tested was that known as the Marconi Bellini Tosi system. This apparatus was employed for some time to obtain trial bearings from ships and fixed stations. In certain directions there appeared to be appreciable errors, but on the whole navigators comparing radio bearings with their estimated positions reported very favourably on the accuracy of the bearings. Finally a detailed calibration was made with the aid of a vessel specially loaned by the Admiralty. This vessel's positions were accurately determined by visual means from the shore and a correction table was prepared from the radio bearings corresponding to visual bearings, as more fully described later.

Following upon the success of the installation at Niton Radio Station the following stations were equipped and calibrated:—Cullercoats, Wick, Portpatrick, Humber, Malin Head.

The directional receiving apparatus is also employed for normal reception of ships' traffic

by the stations and materially assists in overcoming interference due to jamming. The stations at Fishguard, North Foreland, Seaforth, Lands End and Valencia are also equipped with directional receiving apparatus, but on account of unfavourable situations, or pressure of ordinary traffic, are not calibrated for the purpose of giving bearings to ships, the directional apparatus being installed simply on account of its anti-jamming properties. The apparatus employed is identical with that at the other calibrated stations, with the exception of Seaforth, where a rotating loop direction-finder supplied by Messrs. Siemens has been installed.

The aerial system of the direction-finding apparatus consists of two aperiodic, triangular, single-turn loops of large dimensions, the base

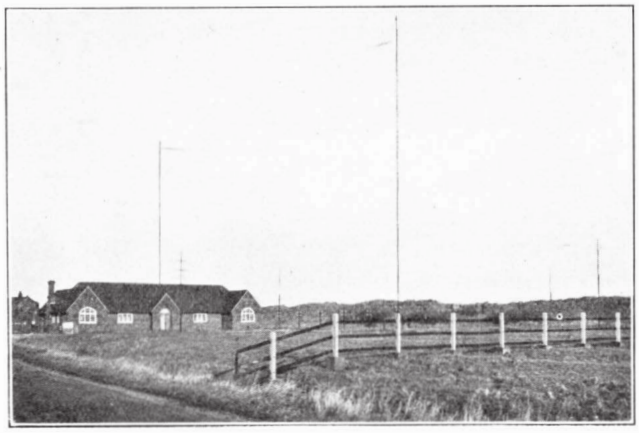


Fig. 1.

of each triangle being of the order of 120 ft. in length and the apex 70 to 100 ft. above the ground. The loops are generally supported in the centre by the main transmitting mast and are at right angles to each other. Fig. 1 illustrates a typical Bellini Tosi directional aerial system. The two pairs of wires from the ends of the loops are led into the building to the receiving apparatus by means of a transposed transmission line as shown in Fig. 2.

The aerials must be electrically symmetrical and balanced, a condition which it is sometimes difficult to fulfil owing to the influence of the transmitting aerial, stays, and other local obstructions. The lead-in is as short as possible and is transposed, and sometimes screened, in order to secure this symmetry and balance which is necessary to give well defined bearings.

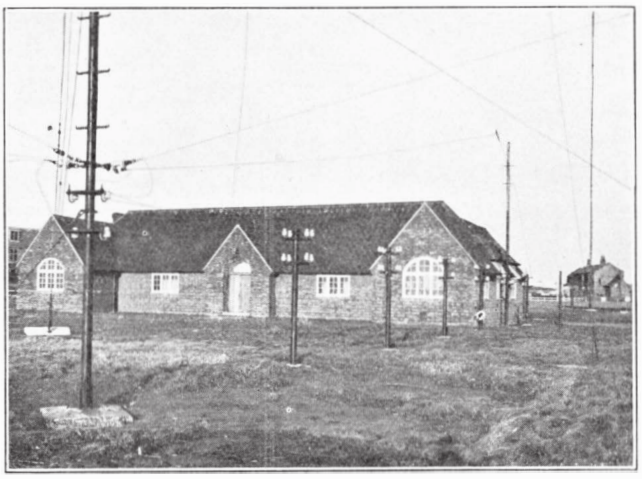


Fig. 2.

A photograph of the receiving apparatus is shown in Fig. 3. The aerials are led into the lower left-hand panel which contains the radio-goniometer. This consists of two coils arranged on a cylindrical former exactly at right angles to each other. One coil is connected to each loop; a search coil capable of rotation in the plane of the two fixed coils provides the coupling between the fixed coils and the receiver. The rotation of the search coil of the goniometer produces the same effect as regards the reception of signals as does the rotation of the frame aerial of a frame aerial receiver. The circular scale on this panel is divided into 360 degrees, the pointer being adjusted to give true North at zero, other bearings being read off in degrees east of true north.

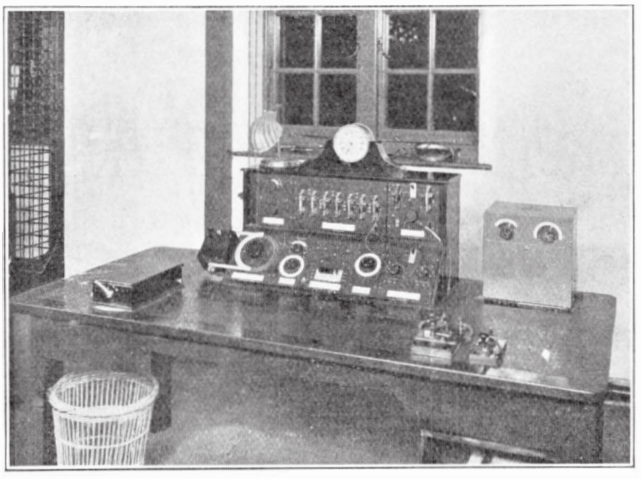


Fig. 3.

A simplified schematic diagram of connections of a Marconi direction-finding receiver is shown in Fig. **4**. The search coil is coupled through a tuned intermediate circuit to a six-stage, aperiodic, high-frequency amplifier and thence to a two-stage low-frequency amplifier. High frequency or low frequency stages may be cut out at will.

ship requiring the bearing calls the Direction-Finding Station and on receiving acknowledgement of its call and instructions to " Go ahead," transmits the code for the request " What is my bearing from you." The Direction-Finding Station then signals the code instruction to send the ship's call sign for 60 seconds. While these signals are being transmitted the shore operator

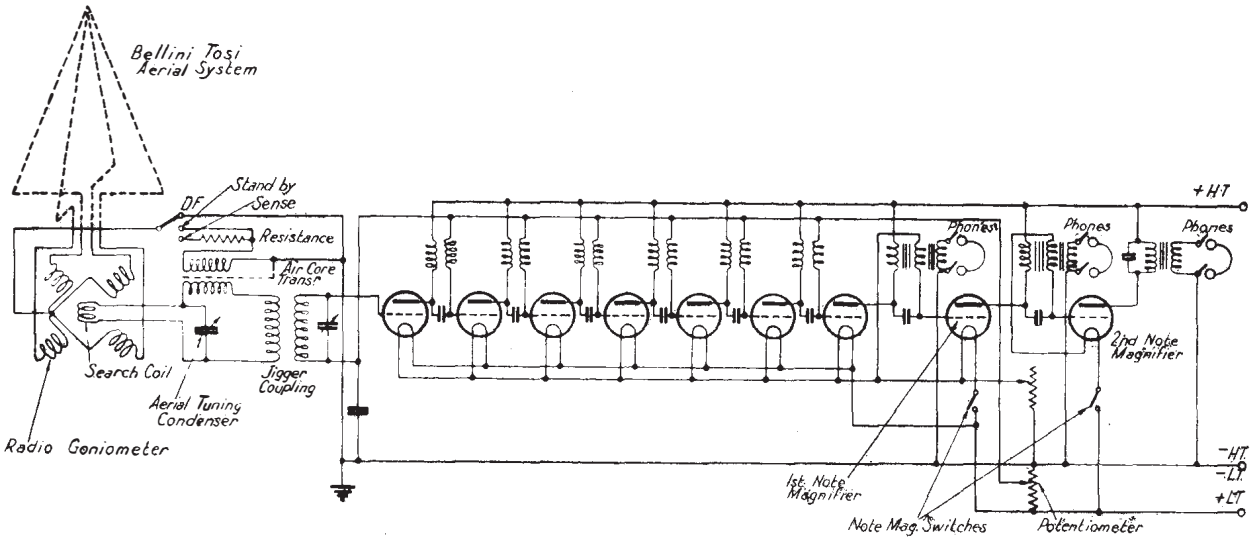


FIG. 4.—SIMPLIFIED SCHEMATIC DIAGRAM OF RECEIVER.

By means of a switch on the high-frequency transformer panel the receiver may be used in either the " stand-by," or direction finder, positions or for " sense " determination. With this switch in the " stand-by " position, the loops are grouped and coupled on to the receiver, so as to form a simple vertical aerial with a circular polar diagram of reception. In the " D.F." position the loops are coupled on to the receiver by means of the rotating search coil in the goniometer and a " figure of eight " polar diagram of reception having two positions of minimum signal strength 180° apart, similar to that produced by a frame aerial, is obtained. The " sense " position gives a combination of the " D.F." and " stand-by " positions producing a " heart-shaped " or " cardioid " polar diagram. This enables the " sense " of the incoming signal to be determined. These polar diagrams of reception are shown in Fig. **5**.

The procedure in giving a bearing is described in detail in the Admiralty List of Wireless Signals and is substantially as follows:—The sets the direction finder to " Sense " by pressing a key, and by observing the approximate position of a single minimum signal obtained by rotating the search coil, determines the approxi-

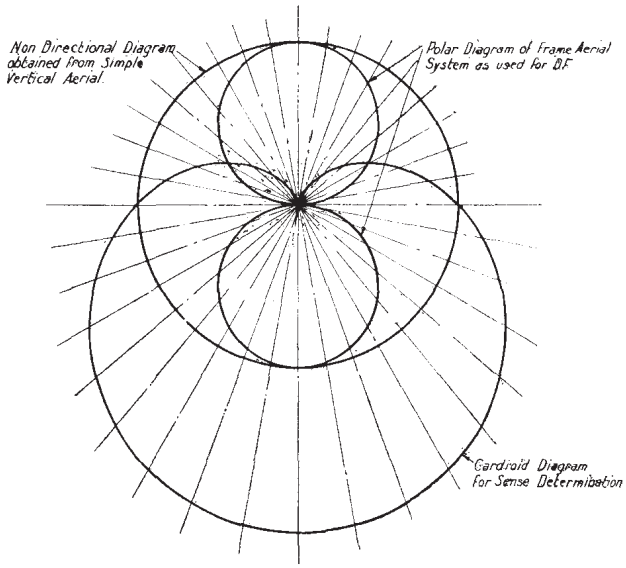

Non Directional Diagram obtained from Simple Vertical Aerial.
Polar Diagram of Frame Aerial System as used for D.F.
Cardioid Diagram for Sense Determination

FIG. 5.—POLAR DIAGRAMS OF RECEPTION.

mate direction of the ship and notes it as "North," "South," "East" or "West." He then sets the key to "D.F.", and after accurately retuning the receiver to the ship's wave-length and adjusting the strength of the received signal to a suitable volume again rotates the search coil. Two positions of minimum signal approximately 180 degrees apart are obtained and these must be determined to within one degree. This is done by swinging the pointer over an arc of a few degrees about the minimum position and noting two positions where signals of equal strength are obtained. The mean of these positions is the required minimum. Four such pairs of readings are taken and used to obtain four means, two for the position corresponding to the approximate direction determined with the key to "Sense" and two for the reciprocal position. The reciprocal readings are then converted to their direction equivalents by the subtraction or addition of 180° and the average of the four means is calculated. From a calibration table the true bearing corresponding to this result is read off and is signalled to the ship. The whole operation occupies about 1½ minutes.

Installation and Calibration of a Direction Finder.

Given ideal site conditions free from obstructions in the form of irregularities of coast line, or ground, groups of trees, buildings, masts, aerial equipment, etc., and with a well-screened receiver housed at the centre of the loops there should be no necessity to apply corrections to obtain a true bearing. In certain cases where errors are of a particular "quadrantal" type the apparatus can be adjusted to give sufficiently accurate readings directly without reference to a calibration table. Such conditions, however, are not obtained at combined coast and direction-finding stations where the site has not been chosen with regard to its suitability for direction finding, where obstructions in the form of masts, aerials and buildings are present, and where the receiver is generally housed in a building about 100 to 150 ft. from the centre of the loops. In these circumstances the aerials are carefully balanced and adjustments to the transmission line and apparatus are made to minimise errors and, finally, the direction-finder is calibrated by comparing the radio bearings of a ship's transmitter at a number of positions with the corresponding positions of the ship obtained by means of accurate visual bearings from the shore.

If the direction-finding Station is on the coast, a theodolite is set up at a convenient point in close proximity to the loops, but giving a wide angle of view over the sea. A telephone circuit connects the theodolite position with the operating position near the direction-finding receiver in the building. A tug or other suitable vessel equipped with wireless apparatus is hired for the purposes of the calibration, and the movements of the tug are controlled by instructions from the theodolite position telephoned to the radio operator in the building and transmitted by radio to the tug.

The distance of the tug from the radio station depends largely upon the weather conditions and visibility. It is usual, however, for the tug to cover the calibrated arc once at a radius of about five miles and to return over the same sector at a radius of about 10 miles. The vessel is stopped about every five degrees for a bearing to be obtained. The vessel remains as stationary as possible for the period of about one minute, during which the bearing is being obtained, but may drift as much as one degree in this time under unfavourable weather conditions. To minimise error from this source, the true bearing is taken by means of the theodolite at the beginning and at the end of the one minute transmission time. The mean of these readings then corresponds with the mean of the four swings taken on the radio-goniometer in the same time. In order to obtain the true bearing from the loops, which are marked on the navigation charts, small correction is applied to the theodolite reading. When the visual and radio bearings have been satisfactorily obtained at one position, the vessel is requested to move to the next position. With favourable weather conditions about forty bearings per day may be obtained and a station completely calibrated in two or three days. The results are plotted in the form of a graph as shown in Fig. **6** which was obtained during a recent calibration at Cullercoats Radio Station. The abscissae give readings obtained on the radio direction-finder and the ordinates give the necessary corrections to be applied in order to obtain true bearings. Fig. **7** shows a similar curve taken for Niton Station.

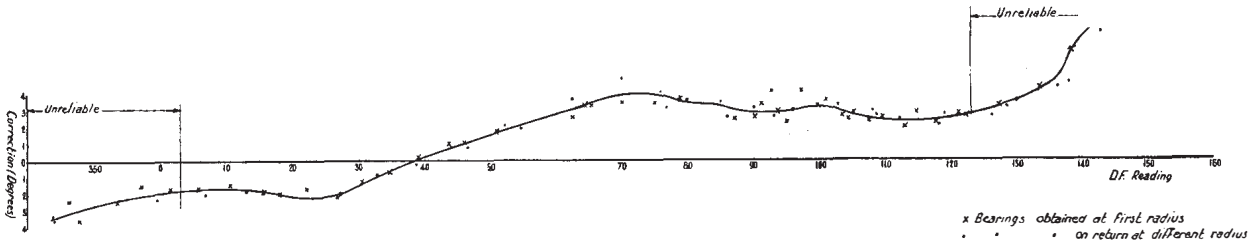


FIG. 6.—CULLERCOATS D.F. CALIBRATION. NOVEMBER, 1929.

The sectors which show any sudden changes or fluctuations in the slope of the correction curve are carefully explored by taking more bearings.

For operating purposes these corrections are tabulated for quick reference.

One of the most serious causes of error is that due to coastal refraction. Radio waves arriving at the coast having a small angle of incidence are refracted in a similar manner to that in which light is refracted upon entering a medium of different density. This error is negligible if the angle of incidence of the wave be large, and in practice all bearings making an angle of more than 20° with the coast line are found to be immune from its effects. All bearings where the angle is less than this are tabulated as " unreliable " and the ship is informed to this effect when a bearing is given in such a sector. The maximum range at which reliable bearings are given is 100 miles.

The procedure of calibrating a direction-finding station which is not in very close proximity to the coast is considerably more complicated. In order to fix the true bearing of the ship from the radio station it is necessary to have two theodolite positions several miles apart on the coast. Simultaneous visual bearings must be taken at each theodolite at the same time as the radio bearing is being taken at the coast station. Communication between the theodolite positions and the radio station is maintained by means of portable radio equipment.

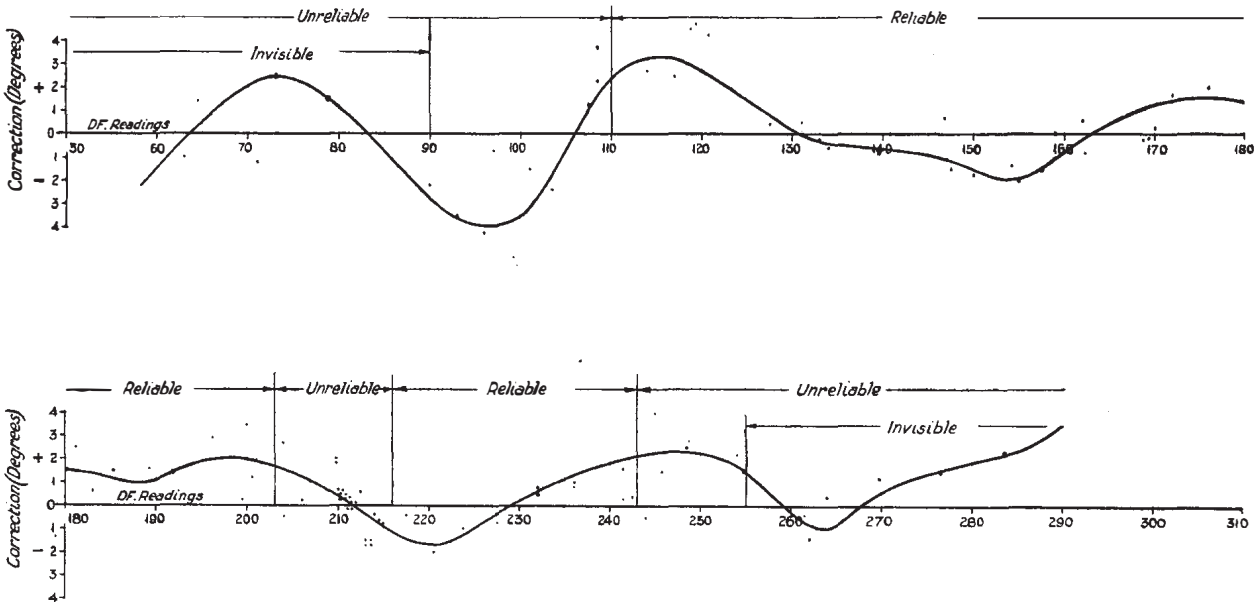


FIG. 7.—NITON RADIO STATION—D.F. CORRECTION CHART—15TH APRIL, 1930.

The stations are recalibrated periodically, or on any occasions when it is necessary to modify the plant of the stations in such a manner as may possibly alter the readings on the direction finder.

In conclusion, it may be stated that the service, for which a small charge is made to the ship, is widely used and provides a valuable aid to navigation under difficult conditions.

DEVELOPMENTS IN BROADCAST RADIO RECEIVING APPARATUS.

A. J. Gill, M.I.E.E., M.I.R.E., and A. G. McDonald, A.C.G.I., B.Sc., A.M.I.C.E.

IN this article it is proposed briefly to discuss some of the more recent developments in broadcast receivers and their components.

The requirements for broadcast receivers are in many respects different from those for receivers used for commercial radio telephony services. For a broadcast receiver, compactness, low first cost, simplicity of operation and high power output are the main essentials. A commercial type of receiver on the other hand can, within reason, be unrestricted in dimensions, it demands the highest degree of selectivity and sensitivity, ability when necessary to operate and furnish a constant level of output under conditions of severe fading and suitability for connection to sharply directional types of antennæ. In addition, adequate measuring equipment must be provided to enable the performance of the receiver as a whole or of any constituent stage to be readily determined. There must also be provision of equipment enabling faults in the apparatus to be immediately notified and located.

Recent progress in broadcast receiver design may be classified under the following headings:

(1) *Increasing use of public supply mains as power supply for receivers.*—This trend has led to the development of methods of rectification for power supply and of special valves using low voltage alternating current for filament heating. In general, the indirectly-heated type of valve, in which the cathode surrounds and is separate from the heating element, has superseded the directly-heated type employing a short thick filament designed to retain its heat and hence its emission during the normal periodic A.C. fluctuations.

An interesting departure from the more usual designs is the use in the Columbia All-electric Receiver No. 304 of ordinary battery type valves, the filaments of which are heated by the D.C. output from a metal-oxide rectifier. This system is quite successful and a similar method using a gas-filled rectifier with the output smoothed by an electrolytic condenser is also satisfactory.

The main reason for the development of all-mains receivers was the fact that suitable high tension supplies could readily be obtained in this way and it was an obvious step to obtain the filament supply in the same manner, thus eliminating all necessity for charging or replacement of batteries. This situation was accentuated by the higher power demands of loud speakers of the moving coil and cone types, which need a considerably greater driving force than that required for the satisfactory operation of the horn type loud-speakers previously in use.

(2) *Improved selectivity combined with high quality.*—The greater power output from the Brookman's Park transmitters has necessitated research into methods of obtaining extreme selectivity without sacrificing quality by cutting the side bands. Filter circuits before the first high frequency valve and cascade connection of two or more screened grid amplifying stages, each with tuned circuits, have been the main lines on which development has taken place. The super-heterodyne receiver with its great possibilities of selectivity does not appear to have received the attention it deserves. This is probably because the early types of super-heterodyne receivers for broadcast reception suffered from two serious defects which made them unpopular. Firstly, the screening of the intermediate frequency stages was insufficient to prevent direct pick-up of stations working in the intermediate frequency band, and, secondly, the selectivity before the first detector was not capable of eliminating strong stations on the opposite side of the beating oscillator. A super-heterodyne receiver, having adequate high frequency selectivity and in which a flatly tuned high gain intermediate frequency amplifier is combined with a correctly designed band-pass filter of the Campbell type to give the necessary selectivity, is probably the ultimate goal in receiver design.

(3) *Extensive use of screening, both of components and of amplifier stages.*—In this case, the design of broadcast receivers has lagged behind the practice in commercial receivers. The question of keeping the cost low may have been

the cause of this delay, but now marked improvements in valve performance and increasing gain per stage has forced the introduction of screening to ensure stability.

(4) *Ganging of controls.*—The use of multi-stage amplifiers has led to ganging of controls in order to enable non-technical users to tune such sets easily. Side-by-side condenser drums were used initially, but the present tendency seems to be to have all condensers ganged on one control with either small parallel condensers for trimming or with some form of clutch to line up the circuits at the ends of the range. For high quality, absolute resonance of all the circuits is not desirable; a double or triple humped response curve is a closer approximation to the ideal flat top curve, so that in this case slight errors in tuning are not necessarily harmful.

(5) *Methods of detection.*—Development in methods of detection has been practically stationary for some considerable time, makers being content with grid leak detection or, exceptionally, using anode bend rectification. It is of interest to note that recently two new systems have been receiving attention, namely, power grid detection and push-pull detection.

(6) *Decoupling schemes and automatic grid bias systems.* — These developments have naturally followed the use of mains power. Decoupling is now employed in all receivers, but methods of obtaining grid bias have not yet become standardised. Free grid bias by tapping across resistances in the negative high tension return is the system usually adopted, although the use of a separate supply from a small metal-oxide rectifier is almost as popular.

(7) *Radio-gramophones.*—Nearly all the better class radio receivers are associated with equipment for the reproduction of gramophone records. The need for higher output from the power stage of the L.F. amplifier has probably been found necessary because of the comparison with the output from an ordinary gramophone. The louder passages need a fairly wide margin of power to give clear reproduction without overloading obscuring the effect.

Since power is obtained from the mains, anode voltages of the order of 350 to 500 are now more or less common. Low voltage power valves giving a large output for low anode voltages are available, but they depend for their high emission on special activation processes. These often are of very fleeting duration and valve lives, for full emission, are undesirably short.

It may perhaps be of interest to note that modern valves are surprisingly variable as regards measured characteristics, and that of ordinary receiving valves tested as high a proportion as 30% are considerably below the makers' published specification. The pumped, as distinct from the gettered valve, is still the best if a long life be desired.

To obtain high tension voltages from A.C. mains a transformer and some form of rectifier is necessary. For low voltages the dry metal oxide rectifier of the Westinghouse Metal, or Igranic Elkon, type is deservedly popular on account of its convenience and long life. For higher voltages the cost of this type of rectifier becomes excessive and a new type of thermionic rectifier, the mercury vapour hot cathode rectifier, is more suitable for these voltages. The new rectifier possesses the high voltage capabilities of a hard vacuum diode with the low and constant volt drop of a mercury arc rectifier. Samples of Messrs. Philips rectifiers tested show a potential drop of 40 volts in 4000, while the General Electric Co.'s G.U.1 shows a drop of 15 volts in 2000. These values are constant for all loads and represent extraordinarily high efficiencies. It will be appreciated that for high power amplifiers and for high tension supplies for transmitters the mercury vapour rectifier has a promising future. Since the potential drop across the valve is small, the heat developed at the anode is also small and consequently the size of the glass envelope can be reduced to a minimum. For example, the G.E. Co.'s G.U.1 type of rectifier, which has a maximum output of 250 milliamperes and a peak reverse voltage of 3000 (half wave), has the same size glass envelope as an ordinary D.E.L. 210 receiving valve.

The reason for the inclusion of mercury vapour is to neutralise the space charge effect which, in a normal thermionic diode, is responsible for the large potential drop, in many cases between 20% and 30% of the total voltage applied to the anode. The space charge effect is due to a proportion of the electrons emitted from a heated filament congregating as a cloud around

the filament instead of flowing on to the anode. This cloud constitutes a negative charge and tends to prevent newly emitted electrons reaching the anode, thus giving rise to a potential drop between filament and plate.

If any gas be present in a valve, it will be ionised when the high tension is switched on, and such ionisation in a soft valve is usually followed by an unduly high anode current and, accompanying this phenomena, is rapid disintegration of the filament by positive ion bombardment from the ionised gas. If, however, the potential drop across the valve can be kept below a certain critical figure, *i.e.*, 22 volts for mercury vapour, the disintegration is prevented. Mercury vapour has an ionisation voltage of 10.4 volts, so that it is a possible gas filling.

Argon and neon have the property of preventing the disintegration of a heated cathode, but such gas fillings are limited to low voltage working. The Tungar, Ediswan and Philips rectifiers all employ inert gas fillings. In general this type of rectifier is most suited to low voltages of, say, 2 up to 500 volts, although 1000 volt rectifiers have been made.

In the new type of rectifier, a hard vacuum is employed and the mercury vapour for providing the ionised electron path is obtained by evaporation from globules of mercury splashed around the sides of the glass envelope. The mercury vapour does not protect the filament from bombardment in the same way as an argon or neon filling does, and it is necessary to limit the current rectified by the valve to the normal electronic emission from the filament.

From this it follows that the high tension voltage must only be switched on when the filament is up to normal heat. If the high tension be switched on without the filament being heated, the resulting ionisation and bombardment breaks up the filament. In tests on one type of mercury vapour rectifier this effect was tested for, and during quite a short interval between switching on and off large pieces of the oxide-coated filament were observed to fly off. This limitation is probably more serious when the rectifier is used for all-mains receivers than when it is used on a transmitter where a delay relay circuit can readily be arranged for. A simple type of bimetallic strip delay relay would be quite suitable for a broadcast receiver to ensure that the anode circuits were not energised until the rectifier filaments were at normal working temperature.

A further interesting characteristic of this rectifier is that its behaviour is entirely different from that of a hard thermionic rectifier in its property of current limiting. An ordinary diode has a limiting output current which is fixed by the electron emission from the filament. The new mercury vapour rectifier does not limit in any way, but if the current passed exceeds the thermionic emission of the filament deterioration of the valve ensues. In operation during the positive cycle the valve is coloured with the blue-green glow of ionised mercury.

A list of valves of this type now available is given below :—

G.E.C.

Type.	GU 1	E 255	E 244	
Filament volts.	4	4	4	
Filament current	3	11	40	amps.
Peak anode current ...	1.5	6.0	15	amps.
Mean rectified current ...	.25	1.0	2.5	amps.
Peak reverse voltage ...	3,000	10,000	20,000	volts.

EDISWAN.

Type.	ESU 75.	
Filament volts.	2	
Filament current	8	amps.
Max. Peak current	.9	amps.
Mean rectified current	.35	amps.
Max. reverse voltage	5,000	volts.

(All the above valves are half-wave).

PHILIPS.

Type No. ...	1061	1071	1062	1077	1072	
Filament volts.	2.1	2.1	2.1	2.1	2.1	
Filament current	2.8	2.8	4.5	4.5	4.5	amps.
Rectified D.C. Output ...	.05	.1	.15	.3	1.0	amps.
Max. anode voltage ...	1000	500	4000	3000	500	volts.

(All the above series are full wave).

The GU1, ESU 75 and 1071 are very suitable for use in amplifiers requiring, say, 80 to 100 milliamps at 400-500 volts, and in the case of the first two mentioned are decidedly the cheapest method of obtaining such a supply. All of these valves use low temperature oxide-coated filaments, so that if they are worked under correct conditions long lives may be expected.

It may be of interest to note that many commercial radio gramophones including the HMV series employ mercury vapour hot cathode rectifiers, while the ESU 75 is extensively used in talking film and public address equipment.

Although the broadcast listener does not require anything like such a high power, the valves

are still suitable for lower powers because of their cheap first cost and high efficiency. The full wave and half wave circuit diagrams for these valves are absolutely identical with those normally used for ordinary thermionic rectifiers. Half-wave rectifiers are used very widely because any unsmoothed ripple is less likely to be unpleasant at 50 cycles per second than it is at 100 cycles per second—the output frequency from a bi-phase rectifier. This is due largely to the diminished output of most moving coil loudspeakers at 50 cycles and their pronounced resonance at 100 cycles.

(8) *Gas-filled Rectifiers.*—Rectifying valves having a gas filling of argon, neon or other gases of the inert series have been made for some considerable time. Complete equipments for battery charging and high tension supply are fairly extensively used, but the use of this type of valve seems to be almost entirely neglected by those who build their own equipment.

In this type of valve the argon or neon filling serves to protect the filament from positive ion bombardment and also from wastage by evaporation. The presence of the argon is also necessary to provide the necessary positive ions to neutralise the space charge. The actual gas pressure used is chosen so that minimum cathode disintegration and maximum anode current are obtained. The gas pressure must be kept fairly low if the valve is required to withstand voltages of the order of 500. This rectifier works on an arc discharge, the conducting gas path being formed by the gas ionised by collisions between the electrons emitted from the filament and the gas molecules.

Valves of this class are very suitable for both battery charging and high tension supply. The ionisation potential is approximately 16 volts. A short list of gas-filled rectifiers is:—

EDISWAN.

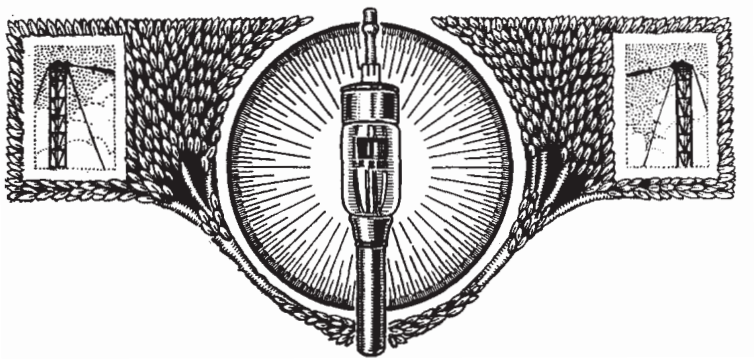
Type.	U 235	U 222	HU 235
Filament volts.	2	2	2
Filament current	3.5	2.5	3.5 amps.
Max. reverse volts per anode	30	150	400 volts. r.m.s.
Max. Output current ...	1.5	.1	.3 amps.

(All the above are full wave).

Messrs. Philips have a very comprehensive series with voltage outputs ranging from 16 to 500 and current outputs from .1 to 40 amperes.

With these valves it is necessary to include in the return lead from the centre tap of the transformer secondary a ballast resistance to take up the difference between the voltage necessary for ionisation 16, and the working voltage, say, 6 to 7 for battery charging. This resistance is usually iron wire in hydrogen and such barreters are designed for each type of valve.

[*Notes on developments under the other headings, outlined above, with special reference to the apparatus at the 1930 Radio Show, Olympia, will be included in the second part of this article.* —*Eds. P.O.E.E.J.*]



NOTES & COMMENTS

BY the courtesy of Mr. S. W. Bassett, who found the documents in an old guard-book in the Lineman's Stores at Oxford many years ago, and Mr. John Darke, we are enabled to publish the following official instructions of earlier times, which were issued before any member of the Engineering Department now serving had entered the service, indeed, before many of them had been born.

The first is dated 9th January, 1871 : its sense is as applicable to-day as it was in '71. Those who run may read, or, as the vulgar say, " A nod's as good as a wink to a blind horse."

POST OFFICE TELEGRAPHS.

Engineer's Department,
North Western Division,
Birmingham.
Jany. 9th, 1871.

To Supts.

Herewith I send you a copy of the Act of 1863—the restrictive clauses of which apply to the Dept.

Supts. and others should always remember the LAW *of the case, but in practice, of course we wish to evade the troublesome part of the restrictions when we can—prudence however will show the point beyond which we must not endeavour to go.*

J. Bolton,
for Div. Eng.

The second is incomplete. The caligraphy is extremely neat and the subject matter deals with the cleaning of insulators which had suffered from a plague of spiders during the heat of the previous summer " both in agricultural and smoky districts."

Birmingham.
19th Sept., 1876.

To Superintendents.

Independent of the special steps in various districts, for which Works order applications have been made, intended to improve our Insulation during the coming winter, there are certain ordinary measures that, if steadily carried out during all the available time of our Linemen, especially those stationed on high roads, must produce most beneficial effects.

Every report I have seen during the present year concurs in stating that the growth of spider webs is most abundant in almost all forms of insulator in ordinary use, and that this is the case both in Agricultural and smoky districts.

No doubt the exceptional heat of the past summer has had something to do with it. It is therefore necessary to take special steps to remove the spider webs and the accumulation of dirt between the cups of the insulators, irrespective of the further steps in the way of washing or changing that may be effected.

If you would issue something like the following to your Inspectors it may be well:—

" Spider webs having accumulated very rapidly in the Insulators on the Road lines during the late Summer, it is necessary

that Linemen proceed at once to take the most energetic steps for their removal.

" Washing and replacing insulators is a special step, arrangements for which will very shortly be made; but the removal of cobwebs is an ordinary duty that a single Lineman can undertake. It is only necessary to pass a piece of cane with the head split open so as to form a rough brush, or a piece of waste secured to the head of a stick, round the inside cup of the insulator to effectively remove cobwebs, and such rubbish attached to them.

" This process can be carried out comparatively rapidly; it requires the carrying of no tools except a ladder, or climbers, and a single . . . . .

Then, as now, depressions approached us from the Atlantic, but it is surprising to find the Department preparing itself a few days ahead for anticipated damage. The hope expressed in the advice of the 30th October, 1877, that no refreshments would be required was not borne out; a marginal note on the side of the paper states " Claims sent in on the 2nd November! "

26th Oct., 1877.

To Supts.

I received following from Engineer this morning and immediately wired you—

" A telegram from New York announces the coming of a strong S.E. gale which will probably strike the British Coast about Saturday next.

" It is so far verified that the wind has been S.E. to-day.

" Of course the date and in fact the occurrence of a storm at all is by no means to be relied on, but seeing the uncertain season we are in it is well to be ready and have all men warned."

Please take necessary steps to have all men in readiness in case of damage.

It will perhaps be as well if your Inspectors came on duty either on Sunday morning or afternoon, if the gale does not appear before, so that in the event of anything happening they may have their men all out in good time in case there are any faults.

F. E. Evans.

To Supts.

The Engineer-in-Chief would be glad to know at once whether you have any, and if so, what Claims to submit in respect of refreshments supplied to men engaged in restoring the communication interrupted by the recent gales.

As the work of renewal was not carried out under any particular disadvantage as regards weather I rather expect you will not have any demands for special allowances.

F. E. Evans.

30th Oct., 77.

The next letter is of important historical significance, since it shows that the Engineer-in-Chief in 1877, instead of regarding the telephone as a scientific toy, is prepared to hire the instrument on a rental basis of £10 per annum for two stations. He is guarded of course in his advice and makes it clear that the Department, while willing to install sets on open lines, does not hold itself responsible for its operation or warrant its satisfactory working. Inductive disturbances are feared, but the use of " low power and slow instruments " on other circuits indicates that the authorities at headquarters were fully aware of the cause of such disturbances. It is still " out of the question to lay a special pipe for any two wires between stations."

Dec. 6, 1877.

To Superintendents.

I have received the following from the Engineer-in-Chief:—

" The Telephone.

" Arrangements have been concluded between the Department and Mr. Reynolds (the Agent for Professor Bell) under which we are now in a position to supply the telephone should it be required.

" I enclose a few circulars received from Mr. Reynolds, from which you will gather the terms he asks: we of course must charge at the same rate.

" Under the arrangements with the patentee the telephone will not be sold out and out, but will be supplied at an annual rental of £5, i.e., for one end—a speaking set to communicate between two places is £10 per annum.

" But, while you are at liberty to make known the fact that the Department does supply this instrument, it is I think right to be very guarded in any opinion you may give as to the circumstances under which the supply can be made.

" A metallic circuit is required for these instruments, i.e., a return wire instead of earth. If the two wires needed therefore can be erected in an isolated position it is clear there is no difficulty in working the telephone; at any rate for reasonable distances. If the two wires on open poles already occupied by other open circuits the working of the telephone will be to some extent interfered with by induction, but if the other circuits are worked with low power and slow instruments, perhaps it will be found that there are many cases in which this induction, though present, does not prevent the telephone speaking. In any cases however in which renters should decide to have wires erected for them for telephonic purposes they must understand that the success of such wires, except when isolated, is at their own risk.

" The chances are that a short wire will work while a long wire will be very materially hampered.

" If underground wires are wanted, for the present they cannot be supplied, as I presume it is out of the question to lay a special pipe for any two wires.

" However, experiments are being conducted in order to ascertain all the circumstances under which the telephone can really be used, and very shortly I shall be able to communicate with you on the point. As yet, go no further than I have said, and be particular to guard against making the Department responsible, or warranting the operations of the telephone in any way. We are obliged by public clamour to adopt it sooner than would otherwise be judicious. Its powers have to be tested; and the chances of improvement have to be developed."

F. E. Evans.

ERRATA IN JULY ISSUE.

The Editors,
I.P.O.E.E. Journal.

Dear Sirs,

With reference to my notes *re* the Manchester Automatic Telephone System, which you were good enough to insert in the July issue of the Journal, I notice the following errors to which attention might be drawn, in order to prevent confusion:—

(1) Page 107, left hand column. At the foot of the page the last sentence should have read: " For this purpose such a group will be divided into two portions. The left hand portion will be used as first choices, etc."

(2) Page 107, right hand column. The last paragraph at the foot of this column should have commenced as follows: " In addition, the first jack of each 5 circuits will have, etc."

(3) Figures 10 and 11 have been interchanged. The title of Figure 10 appears below Figure 11, and vice versa.

(4) In the title of Figure 11, the second line should read: " Code selector level method of multiple fee registration."

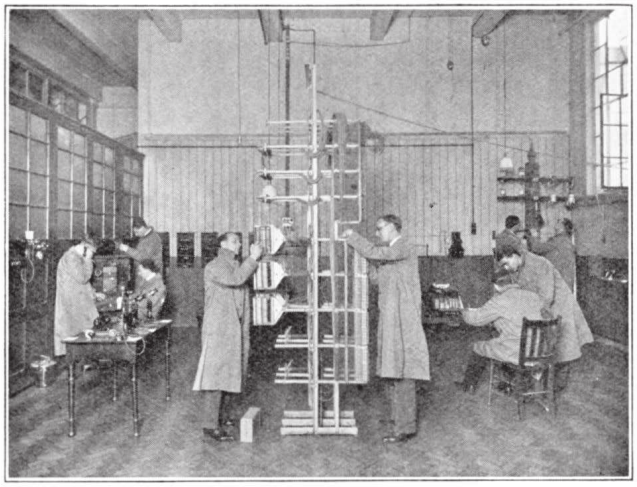
(5) In Figure 12, the " (3d.) " shown against level 4 (BLA), should be deleted.

I am,
Yours faithfully,
L. F. Morice.
18/7/30.

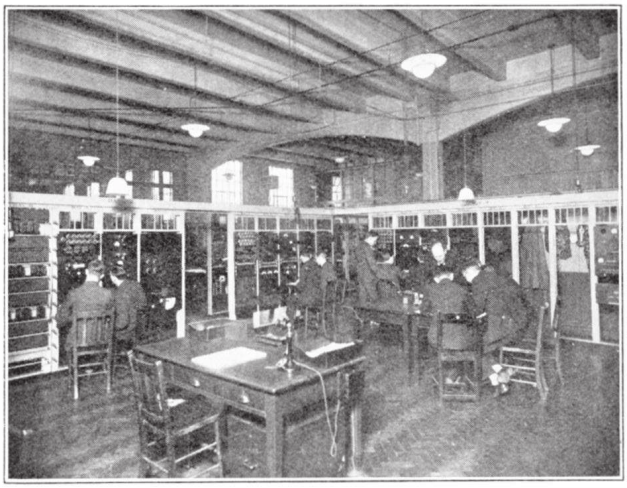
TRAINING.

PROBATIONARY ASSISTANT ENGINEERS AND PROBATIONARY INSPECTORS.

THE training scheme for probationers in the Engineer and Inspector grades has recently been modified. The probationary period of two years is unaltered, the most notable departure from the former arrangement being the introduction of a full time course of instruction extending over a period of 12 weeks at a Headquarters School, on the completion of which the trainees are posted to Engineering Districts for practical training.



GROUP OF STUDENTS IN THE WORKSHOP.



IN THE REPEATER SCHOOL.

The new scheme is applicable to Probationers entering the Engineering Department after the 1st January, 1930, and training commences with the full time course at the Training School, which is intended to deal not only with the scientific and technical aspects of the work of the Engineering Department but also with its general administration and organisation; thus, by giving a general survey of the work and activities of the Department, Probationers are better equipped for practical training in the Districts. The school instruction is in the form of lectures and practical work, such as wiring, soldering, jointing, relay adjustment, the examination of telephone apparatus, etc., and some 100 lectures are given by headquarters officers who possess expert knowledge of particular subjects; a lantern is available for illustrating lectures.

During the school period also, the trainees are conducted over the factories of contractors to the Engineering Department and visit internal and external works in progress in the London Engineering District under the guidance of District officers.

The introduction of the school course has been simplified by utilising the existing training organisation in automatic telephony and Repeater Station practice, additional accommodation having been secured and suitably equipped.

Some of the time is spent at the Research Station, where lectures and practical demonstration in cable balancing and precision testing are given by experts in those subjects.

A liberal number of copies of all technical instructions and regulations is held in the School for reference purposes, and each probationer is supplied with a complete bibliography arranged under the following headings:—

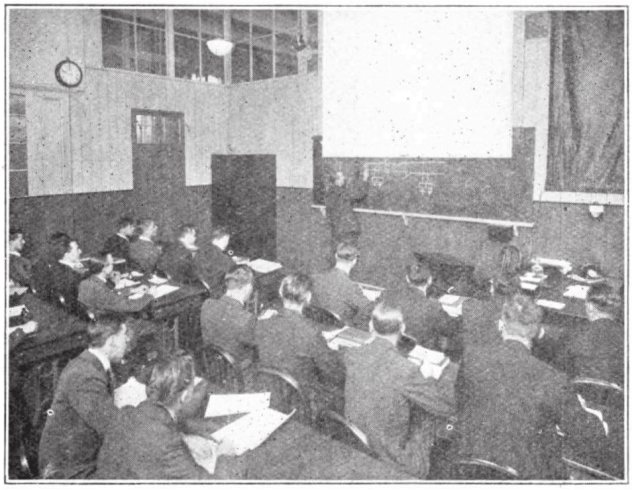
General Telephony.
Automatic Telephony.
Telephone Transmission.
Telegraphy.
External Construction.
Radio Communication.
Carrier Current Telegraph and Telephone Systems.
Organisation, Management and Finance.

The information is scheduled under:—

A. Text books, Treatises, Technical Instructions and Numbered Circulars.
B. Technical Pamphlets, professional papers.
C. Important articles from technical journals.

The bibliography also includes a list, with titles of Technical Instructions, Technical Pamphlets for Workmen and important circulars.

The demand from a recent batch of students for printed papers of the I.P.O.E.E. has been fairly heavy and the library of the Institution has been freely drawn upon.



In a Lecture Room.

The probationers are required while at the School to prepare daily reports bearing upon the lectures, practical work and visits; these are examined by the Officer-in-charge and are returned to the writer for filing as personal notes; suitable loose leaf covers for filing are provided by the Department. The reports are written on foolscap size squared paper, so that freehand sketches can be made quickly and neatly.

The practical work room is equipped with a short pole complete with various standard fittings; a number of sample joints, lengths of cable, samples of " made off " stays, and many special tools are also available. A combined main and intermediate distribution frame is provided; this is cabled and wired by the trainees. A floor pattern P.B.X. and a number of extension instruments are also provided. These are additional to the equipment available in the Automatic School and the Repeater School. The accompanying illustrations will give some idea of the arrangements.

The early part of the morning and afternoon is given up to lectures, the remainder of the time being devoted to practical work, demonstrations and organised reading of Technical Instructions.

An interesting feature of the course is a short reception lecture. This lecture welcomes the probationers, outlines the activities of the Engineering Department, points the way to success in the job, emphasises the need for careful management, both of material and men, indicates the pitfalls, and stresses the need for *service*. This lecture is very greatly appreciated and the newcomer is made to feel that he is joining a great organisation.

Readers of the Journal will appreciate from the following Syllabuses, the extent of the school course. It is recognised, of course, that a detailed knowledge cannot be obtained, but the general survey given by the lectures and the practical work performed, must be of immeasurable value to the Probationer and enable him to get the maximum profit from his District experience.

SYLLABUS A. (4 Lectures).

Reception. Lectures on Organisation.

The functions of the Engineering Department and its relation to other Departments.
Organisation. Engineer-in-Chief's Office, Districts, Sections, Areas.
Territorial and functional organisation in Districts.
Departmental staff tree.
Necessity for co-operation and for co-ordination of works.
Relation with Public Authorities.
Regulations referring:— A^1 to A^4 and D^1.

SYLLABUS B. (10 Lectures).

Telegraph and Telephony. Overhead Construction and Maintenance.

Preservative treatment of poles and timber.
Various types of pole fittings.
Insulators.
Erection of poles.
Distribution of terminal poles.
Properties and use of different types of wire; hard drawn copper, cadmium, copper, bronze, iron and steel.
Suitability and testing of materials employed.
Methods of erecting wires.
Insulated wires used in overhead construction.
Types and use of aerial cables.

Design and construction of aerial cable lines.
Stresses and poles.
Static and kinetic stresses on wires, law connecting dip or sag and stresses.
Factors of safety.
Erection of stays and struts.
Roof standards, brackets and methods of leading in.
Elimination of cross talk by the twist and transposition systems.
Tools and safety appliances; safety first precautions.
Protection from power circuits; power crossings.
Maintenance of overhead lines; Clearing of faults.
Technical Instructions referring:— 3, 8, 13, 15.

SYLLABUS C. (14 Lectures).

Telegraphy and Telephony. Underground Construction and Maintenance.

Iron and earthenware single and multiple way conduits, pipes, bends and couplings.
Troughing.
Manhole and joint box construction.
Types of cables used for trunk and local working.
Construction of leading-in chambers.
Design of dry core and submarine cables.
Jointing wires; twisted, soldered and sleeve joints.
Numbering wires and joints.
Drying joints, plumbing, pressure testing and desiccating.
Installing and joining up loading coils.
Precautions against damage to loading coils.
Precautions against and testing for electrolytic damage to cable sheaths; bonding.
Precautions against interference from power and electric lighting systems.
Divided and multiple way joints.
Termination of trunk and local cables on main frames, on testing tablets and on terminal poles.
Tools and appliances.
Methods of dealing with faults; repairs to cables.
Maintenance organisation.
Safety first precautions.
Development schemes for local telephone areas.
Block wiring.
Technical Instructions referring:— 3, 8, 14, 15, 20.

SYLLABUS D. (15 Lectures).

Telephony. Subscribers' Apparatus. Construction and Maintenance.

Testing and maintenance of Leclanché primary batteries.
The various transmitters and receivers in common use.
Automatic, Central Battery, Central Battery Signalling and Magneto subscribers' instruments.
Extension working (plan numbers).
Automatic and manual branch exchange switchboards.
Power and ringing supply to private branch exchanges.
Party lines.
Call offices.
Common faults experienced.
Maintenance of subscribers' apparatus.
Technical Instructions referring:— 8, 18, 23.

SYLLABUS E. (12 Lectures).

Telephony. Manual Exchanges—Construction and Maintenance.

Magneto, central battery signalling and central battery systems; multiple jacks, operators' telephone circuits, cord circuits, subscribers' and junction circuits.
Main and intermediate distribution frames.
Trunk working.
Layout of exchanges including frames, racks, sections, desks and power plant.
Fault procedure and maintenance organisation.
Exchange transfer procedure.
Technical Instructions referring:— 1, 2, 8, 12, 18, 22, 26, 27.
Circulars E 18, A.T. 103.

SYLLABUS F. (18 Lectures).

Telephony. Automatic Exchanges. Construction and Maintenance.

Reasons for adopting automatic system; advantage and disadvantages; step by step system.
The standard impulse; impulse distortion.
The need for and characteristics of the various tones.
Pre-selectors.
Group and final selectors.
P.B.X. final selectors.
Test and trunk offering arrangements.
Rural automatic exchange apparatus and circuits employed, cabling and wiring, junction arrangements, fault alarm transmissions, call office arrangements, power plant.
Relay design.
Requirements to be met in large (Multi-exchange) areas.
Satellite working; discriminating selectors.
Outline of the director system.
Intercommunication between automatic and manual exchanges. Call indicator "B" position working.
Key Sender "B" position working.
Straight forward junction working.
Trunking and grading; the traffic unit; grade of service.
Cabling and layout of automatic exchanges.
Fault procedure and maintenance organisation.
Routine testers and routiners.
Fault alarm schemes.
Exchange transfer procedure.
Technical Instructions referring:— 25.
Circulars A.T. 101, 104, 105, 106, 109, 110, 111, 112, 113.

SYLLABUS G. (18 Lectures).

Telephone and Telegraph Transmission.
Section I. Telephony.

The voice and ear in telephony.
Limiting transmission factors, attenuation, distortion and noise.
Units for expression of attenuation and line constants.
Transmission standards. Transmission formulae and their application to design of aerial and underground, trunk, junction, and subscribers' circuits. Coil and continuous loading; loaded line constants and characteristics. Phantom telephone circuits.

The transmission effect of each apparatus component in a transmission circuit with special reference to transmitters, receivers, induction coils, transformers and bridging apparatus.
Equivalent networks, electrical filters.
Transmission testing, alternating current bridges.
Voice-ear comparative tests. Tests of transmission efficiency of subscribers' apparatus.
The nature, cause and measurement of cross-talk.
Telephone repeaters 2-wire, 4-wire and cord circuit types; circuits and signalling arrangements.
Transmission circuits employing repeaters; attenuation at different frequencies, amplification limits, reflection, echo and transient effects, echo suppression, time of transmission, singing test for balance comparison, gain measurements, transmission levels.
Line impedance measurement and calculation of repeater balances. Localisation of impedance irregularities in lines.
Brief outline of carrier frequency telephony.
Trans-Atlantic radio telephone circuits.

Section II. Telegraphy.

Fourier Integral. Its application to telegraph transmission theory.
Limiting transmission factors as regards speed of working on long aerial, underground and submarine telegraph lines. Comparative speeds of telegraph systems.
Simultaneous telegraphy and telephony, (superposed and composited working), filters and smoothing circuits.
Long submarine cables. Earth currents and methods of preventing disturbance therefrom.
Technical Instructions referring:— 19, 20, 21.

SYLLABUS H. (10 Lectures).

Telegraphy. Telegraph Apparatus and Circuits.

Wheatstone's A.B.C., single needle, sounder (ordinary and polarised), keys relays, line galvanometers, and condensers. Wheatstone transmitter, receiver and perforator (including keyboard types); Hughes, Baudot and teleprinter apparatus.
Single and double current duplex, central battery, quadruplex, multiplex, Wheatstone automatic, modern type-printing and concentration systems. Use of one battery for a large telegraph office.
Simplex, duplex and high speed repeaters.
Brief outline of voice-frequency telegraphy and photo-telegraphy.
Methods of protecting lines, submarine cables and apparatus from (*a*) Lightning, (*b*) power circuit currents.
Internal wiring of large telegraph offices.
Care and adjustment of sounders, relays, keys, etc. Balancing of duplex circuits. Common faults experienced in telegraph apparatus.
Technical Instructions referring:— 5, 6, 7, 12, 28.

SYLLABUS J. (4 Lectures).

Telegraphy and Telephony. Power Plant.

General description and requirements of power plant.
Power distribution leads, cables, permissible potential drop.
Main, distribution and alarm fuses.
Noise elimination from Exchange power supply.
Ringing machines and tone interrupters, automatic ringing change-over arrangements.
Power board layout and instruments, alarm voltmeters.
Types of prime movers and rectifiers used for battery charging.
Maintenance and operation of power plant and secondary cells.
Emergency power arrangements.
Technical Instructions referring:— 24.

SYLLABUS K. (7 Lectures).

Telegraphy and Telephony. Testing methods and procedure.

Fault localisation. Testing methods in use by Post Office.
Routine maintenance testing (morning test) of long distance lines.
Test desk arrangements at telephone exchanges.
Routine testing at repeater stations.
Precision testing for the localisation of faults in underground cables.
Balancing of cables and acceptance tests.
Technical Instructions referring:— 2, 4, 8, 19, 27.
This instruction will be given at the Research Section, Dollis Hill.

SYLLABUS L. (8 Lectures).

Finance and Administration.

Finance. Vote and Telephone Capital Account. Annual Estimate for Budget purposes. The "Commercial Accounts" of the Post Office.
The preparation of works estimates; direct and indirect charges.
The financial authority of Superintending and Sectional Engineers.
Works orders, Annual Works Orders, departures from estimates.
Engineer's Orders and District Engineer's Orders.
Specification and tenders. Supervision of contract works. Reinstatement of pavings. Certification of accounts.
Local Orders.
The control of labour costs; Unit Maintenance and Construction Costs.
Advice Note procedure.
Repayment Works.
Engineering Department's specification and stores acceptance tests.
Stores; requisitions, delivery and transfer notes, maintenance exchange, loans.
Section stocks, normal stocks, pole stocks, plant lists and tool lists.
Correspondence procedure.
Procedure in case of damage to Departmental or other property.
Procedure in connection with accidental cases.
Powers and obligations of Postmaster General under Telegraph Acts; wayleaves.
Board of Trade Regulations, Home Office Regulations, Factory Acts, etc., affecting the Department.
Regulations referring:— B^1 to B^4, C^1, F^1, G^1 to G^6.
Reg. 88 Provincial Advice Note Procedure.
L.E.D. District Circular 11. do.

SYLLABUS M.

Practical Work.

Forming and lacing switchboard cables.
Soldering wires to tags.
Jointing bronze and copper wire.
Dismantling and re-assembling pieces of apparatus, such as dials and switches; adjusting relays and simple mechanism.

The first course under the modified scheme was completed in June and its success was very largely due to the headquarter's officers who were called upon to deliver the lectures; they may be interested to learn that 800 questions were asked by the students, an average of eight per lecture. This does not include the many questions asked at the informal chat which invariably took place, when a lecture was finished.

By a happy coincidence it was possible owing to the kindness of the Western Electric Co., to show the probationers a film, with sound accompaniment, of the laying of the Newfoundland-Azores submarine cable. This was much appreciated.

C.W.B.

OUTLINE NOTES ON TELEPHONE TRANSMISSION THEORY.

W. T. PALMER, B.Sc., Wh. Ex., A.M.I.E.E.

INTRODUCTION.—There are many excellent text-books written in English bearing on the subject of Telephone Transmission. No one can ever absorb all the information he will need, however, on any particular subject, and in the case of Transmission so much valuable literature exists that those students who merely desire to memorise enough in order to find their way about encounter exceeding difficulty in deciding what may be regarded as of primary practical importance and what may be regarded as of secondary importance. It is mainly for those students that the following brief notes have been written and their perusal is intended to bear the same relation to existing literature (see references at the end of each Section) as the reading of a map bears to a journey in a strange country. Even the reading of a map demands some existing knowledge of physical geography on the part of the student and the perusal of these notes requires some mathematical knowledge, since the solutions of transmission problems are, generally speaking, essentially mathematical in character. For this reason, Section I. reviews the principal theorems and formulæ used in the later notes and a knowledge of the elementary mathematics involved therein should form part of the mental equipment of the intending student of Telephone Transmission at the outset. Section I. also introduces the conventions and symbols which will be adopted in the subject matter of subsequent sections.

SECTION I.

(*a*) *The Binomial Theorem* states that:—

$$(a+x)^n = a^n + na^{n-1} \cdot x + \frac{n(n-1)}{\lfloor 2} \cdot a^{n-2} \cdot x^2 + \frac{n(n-1)(n-2)}{\lfloor 3} \cdot a^{n-3} \cdot x^3 + \ldots\ldots$$

This is true for all values of n. If n be positive, the right hand side contains $(n + 1)$ terms. If n be negative, the number of terms is infinite. Writing $a = 1$ we get:—

$$(1 \pm x)^n = 1 \pm nx + \frac{n(n-1)}{\lfloor 2} \cdot x^2 \pm \frac{n(n-1)(n-2)}{\lfloor 3} \cdot x^3 + \ldots\ldots$$

Further, if $x \rightarrow$ zero (if x approaches zero), we get the much used approximation:—

$$(1 \pm x)^n \fallingdotseq 1 \pm nx$$

(*b*) *The Exponential Theorem* states that:—

$$a^x = 1 + x \log_e a + \frac{x^2}{\lfloor 2} \cdot (\log_e a)^2 + \frac{x^3}{\lfloor 3} \cdot (\log_e a)^3 + \ldots\ldots$$

where $e = 1 + 1 + \frac{1}{|2} + \frac{1}{|3} + \ldots\ldots\ldots\ldots$,

the base of natural or Napierian logarithms.

This Theorem can be derived directly from the Binomial Theorem and the following are the chiefly used forms :—

$$e^{\pm x} = 1 \pm x + \frac{x^2}{|2} \pm \frac{x^3}{|3} + \frac{x^4}{|4} \pm \ldots\ldots$$

and $$\log_e (1 \pm x) = \pm x - \frac{x^2}{2} \pm \frac{x^3}{3} - \frac{x^4}{4} \pm \ldots\ldots$$

which is true when $x < 1$.

(*c*) *De Moivre's Theorem* states that :—

$$(\cos x \pm j \sin x)^n = \cos nx \pm j \sin nx = e^{\pm jnx}$$

where j stands for the imaginary quantity $\sqrt{-1}$. This is true for all values of n. Hence when $n = 1$, we get :—

$$\left.\begin{aligned} e^{jx} &= \cos x + j \sin x \\ \text{and} \quad e^{-jx} &= \cos x - j \sin x \end{aligned}\right\}$$

which are two very important relationships used to a large extent in ordinary classic Transmission Theory. These two relationships can also be derived directly from a consideration of the Exponential Theorem and the expansions of sin x and cos x in powers of x.

(*d*) *The Hyperbolic Functions* are :—

The hyperbolic cosine of $x = \frac{e^x + e^{-x}}{2}$

and is written—

$$\cosh x = \frac{e^x + e^{-x}}{2}$$

The hyperbolic sine of $x = \frac{e^x - e^{-x}}{2}$

and is written—

$$\sinh x = \frac{e^x - e^{-x}}{2}$$

The hyperbolic tangent of $x = \frac{e^x - e^{-x}}{e^x + e^{-x}}$

and is written—

$$\tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

From De Moivre's Theorem we have :—

$$\cos x = \frac{e^{jx} + e^{-jx}}{2} \quad \text{and} \quad \sin x = \frac{e^{jx} - e^{-jx}}{2j}$$

Writing jx for x we get :—

$$\cos jx = \frac{e^x + e^{-x}}{2} \quad \text{and} \quad \sin jx = \frac{-e^x + e^{-x}}{2j} = \frac{j(e^x - e^{-x})}{2}$$

Hence by the foregoing definitions of the hyperbolic functions we have :—

$$\left.\begin{aligned} \cosh x &= \cos jx \\ j \sinh x &= \sin jx \\ j \tanh x &= \tan jx \end{aligned}\right\}$$

and also :—

$$\left.\begin{aligned} \cosh jx &= \cos x \\ \sinh jx &= j \sin x \\ \tanh jx &= j \tan x \end{aligned}\right\}$$

These form the principal relations between the trigonometrical and hyperbolic functions.

From these relationships it is possible to convert an expression containing hyperbolic functions into one of ordinary trigonometrical functions, or *vice versa*, and frequent use is made of such conversions. (See paragraph (*g*)).

Fig. **1** shows curves of the hyperbolic functions and one of the most important features shown by these curves is that *for values of* $\theta \geqslant 2$ *we have* $\tanh \theta \fallingdotseq 1$ *and* $\sinh \theta \fallingdotseq \cosh \theta$.

(*e*) *Vector Quantities.*

All quantities can be divided into two main classes viz., scalar and vector. The former have magnitude only, but the latter possess in addition to magnitude, three other important attributes—

(1) Point of application.
(2) Direction or line of action.
(3) Sense or way along that line.

The essential feature of vector quantities is *direction*. All other quantities are scalar as they can be drawn to scale but do not involve direction, *e.g.*, mass, length, volume, etc. Examples of vector quantities are force, velocity, momentum, electric current and potential, etc.

A vector quantity can be completely represented by a straight line such as OP, Fig. **2**(*a*), where ● is the point of application, the length OP to scale represents the magnitude in units of the quantity considered, the angle θ gives the direction with respect to a fixed line OX and the arrow gives the sense or way along the line OP.

If the length of OP contains A units we repre-

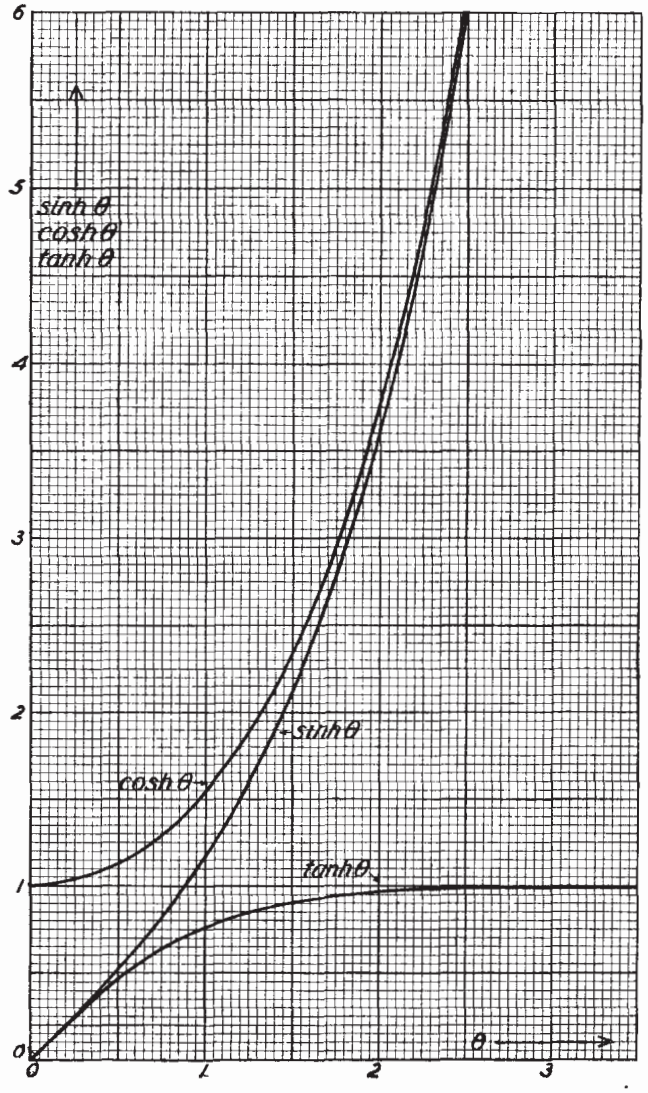


FIG. 1.—CURVES OF SINH θ, COSH θ AND TANH θ.

sent the vector shown in Fig. 2(*a*) by the symbol:—

$$A, \theta \text{ or } A \angle\theta$$

If OP is in the position shown in Fig. 2(*b*) we represent such a vector by the symbol—

$$A, -\theta \text{ or } A \angle -\theta$$

In other words, a clockwise rotation from OX is said to generate a positive angle and an anti-clockwise movement a negative angle.

A is called the *modulus* of the vector and θ the *argument*.

Consider Fig. 2(*a*) and imagine OP to rotate clockwise with uniform angular velocity ω radians per second and that OP is in the position

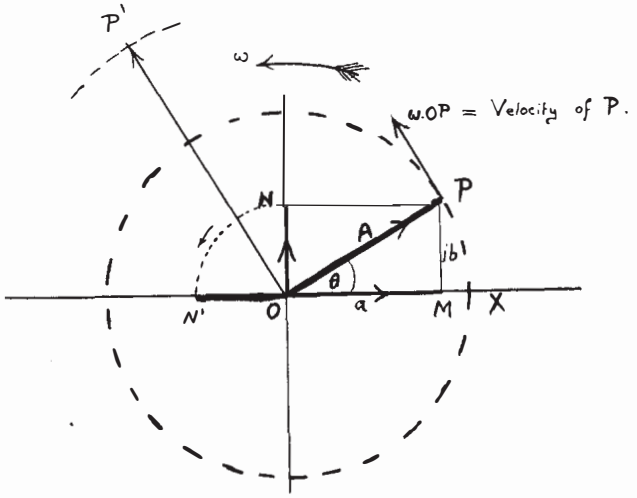


FIG. 2(*a*).

OP represents a vector quantity of magnitude A, having direction θ with the fixed line OX, the symbolical representations being shown in Table I., first column: $A = \sqrt{a^2 + b^2}$.

shown after t seconds from the initial or zero position OX, *i.e.*, $\theta = \omega t$. Now resolve OP into horizontal and vertical components OM and ON respectively. If OM = a units, ON = b units, then the vector OP = A units can be also represented by the symbols—

$$\sqrt{a^2 + b^2} \angle\omega t \text{ or } a + jb$$

where j signifies a positive movement of $\frac{\pi}{2}$ *radians for b and* $\tan \omega t = \frac{b}{a}$

By considering paragraph (*c*) and the expression—

$$e^{jx} = \cos x + j \sin x,$$

and since $a = A \cos \omega t$, $b = A \sin \omega t$ one can represent the vector OP mathematically by yet another symbol, viz.,

$$Ae^{j\omega t} \text{ or } \sqrt{a^2 + b^2} \cdot e^{j\omega t}$$

which constitutes a very important form and one which enables many vector operations to be performed more rapidly than by the use of the form $a + jb$.

Similarly if OP is in the position shown in Fig. 2(*b*) we represent it symbolically by

$$\sqrt{a^2 + b^2} \angle -\omega t \text{ or } a - jb$$

where $-j$ signifies a negative movement of

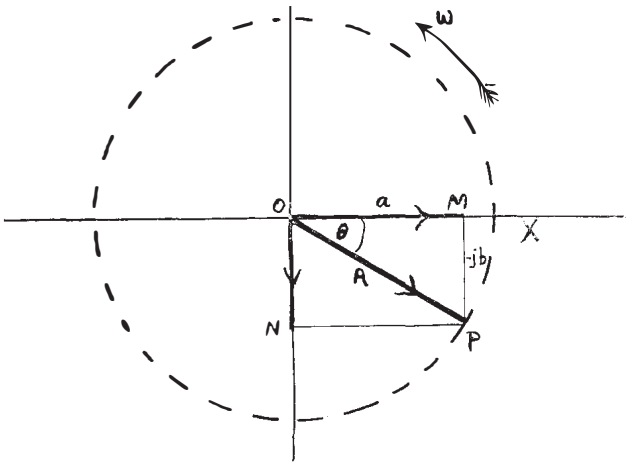


FIG. 2(*b*).

OP represents a vector quantity of magnitude A, having direction $-\theta$ with the fixed line OX, the symbolical representations being shown in Table I., second column : $A = \sqrt{a^2 + b^2}$.

$\frac{\pi}{2}$ *radians for b and tan* $\omega t = \frac{b}{a}$, and in this case the vector OP can be also represented mathematically by the symbol :—

$$Ae^{-j\omega t} \text{ or } \sqrt{a^2 + b^2} \cdot e^{-j\omega t}$$

NOTE.—Any symbol could be used to denote that b were turned through $+ 90°$ from the direction OX. Thus suppose we let ON $\equiv \eta b$ in Fig. **2**(*a*) where η denotes for b a clockwise rotation of 90° from the direction OX. Then, by this convention, η ON denotes that ON is turned through a further $\frac{\pi}{2}$ radians, and we come to the position $ON^1 = -b$, *i.e.*, $\eta(\eta b) = -b$, *i.e.*, $\sqrt{-1} \times \sqrt{-1} \times b$. Hence the effect of the operation with η (rotation through 90°) can be considered as mathematically equivalent to multiplication by $\sqrt{-1}$. But the usual mathematical symbol for the imaginary quantity $\sqrt{-1}$ is j (see paragraph (*c*)), and therefore it is customary to use j to denote the geometric operation of rotation through 90°.

To summarise the various ways by which a vector may be represented, other than by an actual line, Table I. has been drawn up showing the five principal symbolic methods. The third column indicates the vector operations for which the form is best suited and the following paragraph summarises the principal vector operations required.

TABLE I.

VECTOR REPRESENTATION BY SYMBOLS.

Positive Angles.	Negative Angles.	Suitable for :—
$a + jb$	$a - jb$	Addition and subtraction.
$\sqrt{a^2 + b^2}\,(\cos \omega t + j \sin \omega t)$	$\sqrt{a^2 + b^2}\,(\cos \omega t - j \sin \omega t)$	
$\sqrt{a^2 + b^2} \cdot e^{j\omega t}$ or $A \cdot e^{j\theta}$ or $\sqrt{a^2 + b^2}\ \underline{/\theta}$	$\sqrt{a^2 + b^2} \cdot e^{-j\omega t}$ or $A \cdot e^{-j\theta}$ or $\sqrt{a^2 + b^2}\ \underline{/-\theta}$	All operations, except addition and subtraction, such as multiplication, division, etc.—See paragraph (*f*).
$\sqrt{a^2 + b^2}\ \tan^{-1}\frac{b}{a}$	$\sqrt{a^2 + b^2}\ \tan^{-1} -\frac{b}{a}$	—

(*f*) *Simple Vector Operations.*

(1) *Addition of Vectors* :—

$$(a+jb)+(c+jd) = (a+c)+j(b+d)$$
$$= \sqrt{(a+c)^2+(b+d)^2}\ \underline{/\tan^{-1}\left(\frac{b+d}{a+c}\right)}$$

(2) *Subtraction of Vectors* :—

$$(a+jb)-(c+jd) = (a-c)+j(b-d) \text{ or}$$
$$= (a-c)-j(d-b)$$
$$= \sqrt{(a-c)^2+(b-d)^2}\ \underline{/\tan^{-1}\left(\frac{b-d}{a-c}\right)}$$

(3) *Multiplication of Vectors* :—

$(a + jb)(c + jd)$ must be thrown into the form $Ae^{j\theta} \times Be^{j\phi}$ which gives the single resultant vector—

$$AB\, e^{j(\theta + \phi)}$$

Hence the rule—"*Multiply* the moduli and *add* the arguments."

(4) *Division of Vectors* :—

As before we write $(a + jb) \div (c + jd) = \frac{Ae^{j\theta}}{Be^{j\phi}}$ which gives the single resultant vector—

$$\frac{A}{B} \cdot e^{j(\theta - \phi)}$$

Hence the rule—"*Divide* the moduli and *subtract* the arguments."

(5) *Involution and Evolution of Vectors* :—

$(a + jb)^n = A^n e^{jn\theta}$

$\sqrt[n]{(a + jb)} = \sqrt[n]{A} \cdot e^{j\frac{\theta}{n}}$ *e.g.*, If $n = 2$ this becomes $\sqrt{A} \cdot e^{j\frac{\theta}{2}}$.

Hence to take the square root of a vector—"Obtain the *square root* of the modulus and *halve* the argument."

$$\frac{(a + jb)^n}{\sqrt[m]{(c + jd)}} = \frac{(A \cdot e^{j\theta})^n}{(B \cdot e^{j\phi})^{\frac{1}{m}}} = \frac{A^n}{\sqrt[m]{B}} \cdot e^{j\left(n\theta - \frac{\phi}{m}\right)}$$

(6) *Differentiation of Vectors* :—

$\frac{d}{dt}(Ae^{j\omega t}) = j\omega A \cdot e^{j\omega t}$ and $\because j$ when written in the $a + jb$ form $= 0 + j.1$, which is $= e^{j\frac{\pi}{2}}$, this expression becomes—

$$\omega A \cdot e^{j\left(\omega t + \frac{\pi}{2}\right)}$$

which is another vector 90° of phase ahead of $Ae^{j\omega t}$ and ω times its amplitude.

NOTE.—It is interesting to note that this result can be obtained directly from consideration of the diagram shown in Fig. **2**(*a*) where the rate of change of OP with regard to time is at any instant equal to ω . OP, is tangential as shown by the line PV, *i.e.*, a vector 90° ahead in phase and ω times the amplitude OP, and can be represented by a line to scale such as OP′ at right angles to OP, where OP′ $= \omega$. OP.

(7) *Integration of Vectors* :—

$$\int Ae^{j\omega t} \cdot dt = \frac{A}{j\omega} \cdot e^{j\omega t} = -j\frac{A}{\omega} \cdot e^{j\omega t}$$
$$= \frac{A}{\omega} \cdot e^{j\left(\omega t - \frac{\pi}{2}\right)}$$

which is another vector 90° behind $A \cdot e^{j\omega t}$ and $\frac{1}{\omega}$-times its amplitude.

This result can be obtained by consideration of Fig. **2**(*a*), where the time integral of the vector OP′ is OP, which is a vector 90° behind the phase of OP′, and OP $= \frac{1}{\omega}$. OP′.

(8) *Logarithm of a Vector* :—

$$\text{Log}_e(a + jb) = \log_e A \cdot e^{j\theta}$$
$$= \log_e \sqrt{a^2 + b^2} \cdot e^{j \tan^{-1}\frac{b}{a}}$$
$$= \log_e \sqrt{a^2 + b^2} + j \tan^{-1}\frac{b}{a}$$

which is a vector expressed in the form $a + jb$.

(*g*) *Hyperbolic Trigonometry.*

The hyperbolic functions are analogous functions of the area of the hyperbolic sector, to the functions which ordinary trigonometrical ratios bear to the area of the sector of a circle. Thus we have :—

(1) Referring to Fig. **3**(*a*) :—

Area of the circle .—... $\frac{x^2}{a^2} + \frac{y^2}{a^2} = 1$

θ (radians) ..... $\frac{2 \times \text{area of sector}}{a^2}$

$\sin\theta = \frac{y}{a} = -\frac{1}{2}j(e^{j\theta} - e^{-j\theta})$; $\cos\theta = \frac{x}{a} = \frac{1}{2}(e^{j\theta} + e^{-j\theta})$:

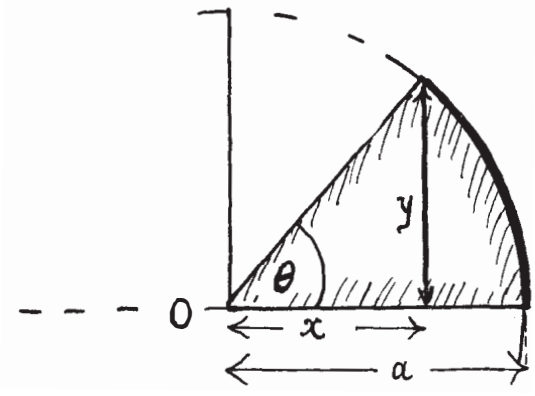


FIG. **3**(*a*).

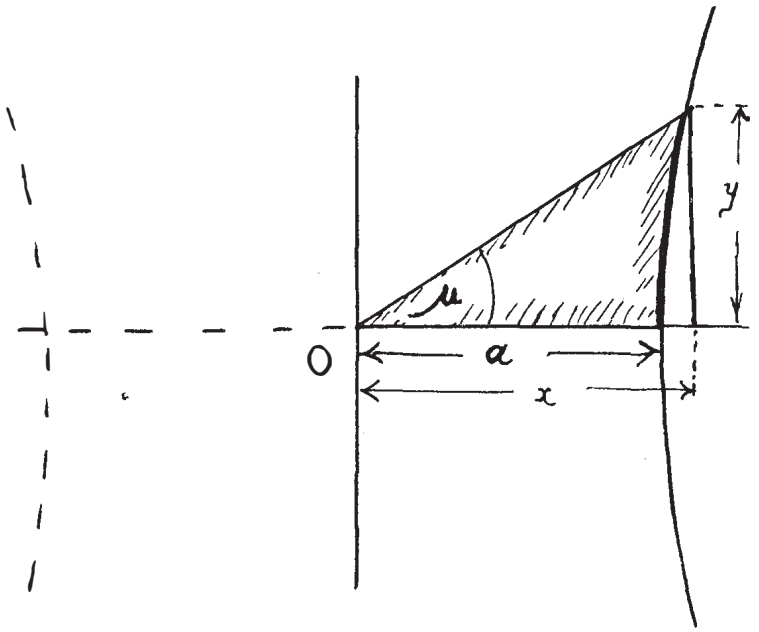


FIG. 3(*b*).

(2) Referring to Fig. 3(*b*) :—

Area of hyperbola ..... $\frac{x^2}{a^2} - \frac{y^2}{a^2} = 1$

μ (hyps) ..... $\frac{2 \times \text{area of sector}}{a^2}$

Sinh $\mu = \frac{y}{a} = \frac{1}{2}(e^{\mu} - e^{-\mu})$; cosh $\mu = \frac{x}{a} = \frac{1}{2}(e^{\mu} + e^{-\mu})$

The following list is intended as a resumé of only the principal hyperbolic trigonometrical formulæ used in the solution of transmission problems and which should be committed to memory. For the numerous other formulæ and proofs reference should be made to the text-books indicated at the end of the Section. It will be noticed that similarity exists between the hyperbolic and trigonometrical formulæ, except for sign in some cases.

Principal Hyperbolic Relations required :—

1. Sinh $(a \pm b) = \sinh a \cosh b \pm \cosh a \sinh b$

2. Cosh $(a \pm b) = \cosh a \cosh b \pm \sinh a \sinh b$

3. Tanh $(a \pm b) = \frac{\tanh a \pm \tanh b}{1 \pm \tanh a \tanh b}$

Complex Hyperbolic Angles :—

4. Sinh $(a \pm jb) = \sqrt{\sinh^2 a + \sin^2 b} \; \angle \tan^{-1}\left(\frac{\tan b}{\tanh a}\right)$

5. Cosh $(a \pm jb) = \sqrt{\sinh^2 a + \cos^2 b} \; \angle \tan^{-1}(\tan b \tanh a$

6. Tanh $(a \pm jb)$ when required is best evaluated from the values of sinh $(a \pm jb)$ and cosh $(a \pm jb)$, thus :—

$$\tanh (a + jb) = \sqrt{\frac{\sinh^2 a + \sin^2 b}{\sinh^2 a + \cos^2 b}} \; \angle \tan^{-1}\left(\frac{\frac{\tan b}{\tanh a} - \tan b \tanh a}{1 + \tan^2 b}\right)$$

In (4), (5) and (6) the complex angle is expressed on the right hand side as an ordinary vector quantity, easily interpretable physically, and in the form necessary for the evaluation of numerical examples.

Useful Text-books and References for Section 1.

" Plane Trigonometry " (Parts I. and II.), by S. L. Loney. Published by Cambridge Univ. Press.

" Elementary Algebra " (Parts I. and II.), by W. M. Baker and A. A. Bourne. Published by G. Bell & Sons.

" Elementary Treatise on Conic Sections," by C. Smith. Published by McMillan & Co., Ltd., *or*

" Elements of Co-ordinate Geometry," by S. L. Loney. Published by McMillan & Co., Ltd.

" First Steps in the Calculus," by A. F. Van Der Heyden. Published by Edward Arnold, London.

" Differential Calculus for Beginners," by J. Edwards. Published by McMillan & Co., Ltd.

" Integral Calculus for Beginners," by J. Edwards. Published by McMillan & Co., Ltd.

" Elementary Treatise on Differential Equation," by H. T. H. Piaggio. Published by G. Bell & Sons, London.

" Vector Analysis," by J. G. Coffin. Published by John Wiley & Sons, New York, and Chapman & Hall, Ltd., London.

" Heaviside's Electromagnetic Theory," Vol. I., Chapter III. Published by " The Electrician " Co.

" Alternating Currents," by A. Hay. Published by Harper & Bros., London and New York.

" Hyperbolic Trigonometry," by E. W. Hobson.

For those students not familiar with simple vector operations it is advisable to work concrete examples from some other branch of Science, say, Mechanics—force, velocity, etc.—before applying the principles to the electric circuit. In this connection the following references contain useful information :—

" Applied Mechanics for Beginners," by J. Duncan. Published by McMillan & Co., Ltd.

" Mechanics for Engineers," by A. Morley. Longmans, Green & Co.

HEADQUARTER'S NOTES.

EXCHANGE EQUIPMENT.

The following works have been completed :—

Exchange.	Type.	No. of Lines
Welbeck	New Auto.	8060
Carlton	,,	635
Arnold	,,	450
Beeston	,,	730
Bulwell	,,	540
Addiscombe	,,	2700
Blackpool North Shore ...	,,	785
Blackpool South Shore ...	,,	1745
Fairfield	,,	2700
Rochford	,,	200
Southend	Auto Extn.	Obsn. Equipt.
Portslade	,,	300
Hindhead	New Manual	650
Romford	,,	1780
Scotstoun	,,	2200
Jesmond	Manual Extns.	600
Eastbourne	,,	2120
Didsbury	,,	900
Wembley	,,	1340
Popesgrove	,,	1420
Guildford	,,	940
Rockferry	,,	1040
Woking	,,	400
Cambridge	,,	1480
Lanarkshire C.C.	P.A.B.X.	30
Hollins & Co.	,,	30
Reading University	,,	20
C. Lloyd	,,	20
Strachan & Co.	,,	20
Constructors, Ltd.	,,	20
Crowe & Co.	,,	20
Johnson & Johnson	,,	30

Orders have been placed for the following works :—

Exchange.	Type.	No. of Lines
Rhos	New Auto.	900
Liberton	,,	350
Perivale	,,	4460
Reliance Tandem	,,	—
Colinton	,,	590
Prospect	,,	5700
St. Helens	,,	2100
Prescot	,,	380
Evington	,,	800
Byron	,,	2200
Bedford	Auto Extns.	200
Portslade	,,	300
Western Park	,,	300
Hove	,,	900
Ewell	New Manual	1220
Downland	,,	1000
Eccles	Manual Extn.	560
Bradbury Agnew	P.A.B.X.	Re-arrangements
Johnson & Johnson	,,	30
Price Taylor	,,	20
Widnes Corporation	,,	30
Allmey & Layfield	,,	—

New Rural Automatic Exchanges continue to be opened at the rate of about 10 per month. In the next issue of the Journal it is proposed to include an account of this interesting feature of British telephone progress.

LONDON AND OTHER DISTRICT NOTES.

LONDON DISTRICT.

Growth of Telephone System.

During the quarter ended June 30th, 1930, the nett increase in Exchange lines and Stations was 5,045 and 9,459 respectively. During the same period there was an increase in the local line mileage of 19,300 miles of loop, of which 50 miles were overhead.

New Exchanges.

During the quarter the following automatic exchanges were opened:—

Addiscombe with an initial capacity of 3390 lines
Shepherds Bush ... ... 4000 lines
Fairfield (Croydon) ... ... 2820 lines

The last named exchange is the first to be equipped with meters for registering excess fee calls.

A new C.B. exchange with an initial capacity of 1,020 lines has been opened at Loughton to replace a Magneto Exchange.

It is unique to record the opening in the London Area of a rural automatic exchange. This is situated in a truly rural area—so much so that it was decided not to place a kiosk on the site but to erect it about a quarter of a mile away. The exchange is situated near Passingford Bridge which is on the London-Ongar road three miles beyond Abridge, Essex, and was opened for traffic on Monday, August 18th.

The building is of standard construction and is equipped with one "Unit Auto No. 5." The actual transfers to the new exchange were five subscribers—four from Loughton Exchange and one from Chigwell Exchange—but the exchange opened with ten new subscribers and a Kiosk, making 16 working lines in all. Two junctions are provided to the "parent" exchange at Theydon Bois which is approximately five miles distant.

New T.S.B. Test Room.

Many Engineers throughout the country are familiar with the Test Room in the basement of the Central Telegraph Office, and will therefore be interested in the changes which have recently been made.

The old test room had been in existence for over 30 years and although various modifications were made as necessary in order to adapt it to changing conditions it was realised that the limit of adaptation had been reached, and it was determined to remodel the whole lay-out in a new test room.

The main frame in this test room accommodates the whole of the main and local telegraph and phonogram lines terminated in the C.T.O., a large number of through telegraph and exchange junction circuits and all headquarters exchange lines and telephone extensions connected to the "Official" P.A.B.X.

Two specially designed test desks, each of two positions, have been installed to deal with the telegraph line testing work. The desks are equipped with the usual testing keys, plugs, lamp indicators, voltmeters, but in addition have milliammeters and telegraph galvanometers. The circuits are of course adapted to the special requirements of telegraph circuit testing.

In the new test room is also housed the main chronopher and the sub-chronopher controlling the International Time Signal sent out by radio from the Rugby transmitter.

The transfer of the chronopher and its subsidiary apparatus had to be carried out between two consecutive transmissions of the time signal. This involved much preparation as high precision control clocks had to be shifted to the new room between one hourly signal and the next so that the correction from Greenwich Observatory would not be missed.

The chronopher signalling apparatus was transferred intact, but the connections for the many time and clock circuits and power feeds had to be completed first for the next hourly signal and then for the next International signal. The work was carried through without a hitch.

Excavations in London Wall.

In connection with the growth of the telephone system it has recently been necessary to make excavations in the historic thoroughfare known as London Wall. It was known that somewhere beneath the surface were the remains of the wall which was built by the Romans to surround the

ancient City of London although its exact position was uncertain.

Added interest was therefore given to recent duct laying operations by Messrs. Greig and Matthews, the Department's Contractors, who found it necessary to tunnel through a section of the Roman Wall before they could obtain a clear route for a section of 16 octagonal ducts. It is doubtful whether so much of the original Roman masonry and tiling has been brought up to the surface before at one spot and budding archæologists who were members of City Offices had golden opportunities of closely examining some samples of Roman building material.

The tunnelling operations through the wall commenced from the manhole at the junction of London Wall and Moorgate Street at a depth of about 11 feet and extended some 46 feet diagonally through the wall in the direction of Wormwood Street. The wall at this point lies just below the carriageway foundation on the North side of London Wall. It is four feet thick and formed of irregular blocks of Kentish rag stone firmly bound together in a mortar composed of lime and small flints. At roughly each 2½ feet height of wall a layer of three tiles mortared one over the other runs along the entire length, forming a strong course, the tiles being large ones of 17½″ × 12¼″ and 1½″ thick. The depth of the wall, or rather height, if it were completely exposed, is not recorded so far as this end of London Wall is concerned, but some time ago building excavations farther along London Wall disclosed the base of the wall at a depth of 30 feet below the street level.

Exposed sections of the Roman Wall in London Wall itself can be seen at All Hallows Church at the Wormwood Street end and at St. Alphage Burial Ground at the Wood Street end.

The subsoil of London Wall is now so congested with sewers and mains of the various undertakers that it is a physical impossibility to lay any more conduits at a reasonable depth unless the course of the Roman Wall is completely followed—a pleasant prospect for the next undertaking that requires mains along this route.

Pneumatic Tubes—Localisation tests for stoppages under the streets.

Although it is generally known that there is a pneumatic tube system under the streets of London for the conveyance of telegraph messages it may be a surprise to many to know that the total length of these tubes exceeds seventy miles. Special precautions are taken when the tubes are laid to ensure that the carriers will pass freely, but faults occur at times owing to the operations of other undertakings causing a fracture or indentation of the tube which is not immediately revealed. A stoppage may also be caused by a defective carrier which sticks in the tube.

It is of importance to locate quickly the exact locality of the stoppage as, apart from the delay to the messages contained in the defective carriers, the tube cannot be used for the despatch of other messages until the defect has been remedied.

A brief description of the method of locating the position of a stoppage may therefore be of interest:—

The apparatus utilised consists of a standard carrier made captive by attaching thereto a length up to eight hundred yards of strong twine wound on a reel similar to that used by anglers and mounted on a small iron frame. An approximation to ascertain in which section of the tube the obstruction exists is first made by sending a free carrier to the fault on pressure or vacuum, and timing it back on vacuum or pressure, the normal transit time for the whole length being already known. The captive carrier is then inserted at a test point nearest to the faulty section and blown or sucked, as the case may be, to the point of the obstruction. The length of string run out is then measured and a street opening made at the point thus found.

Judging by the results obtained by this method, the test may be regarded as a most reliable one. For example two street faults were recently cut out of a tube and the distances indicated from the testing points were 90 and 111 yards respectively. In each case the fault was found at the exact point where the ground was first opened.

The position of a bad leak in a street tube is determined by sealing the far end and allowing the captive carrier to travel to the leak under pressure. If the carrier should travel beyond the leak this will be indicated by the lessened pull on the string which takes place as soon as the leak is passed. The distance to the fault is then found by measuring the string in the same

manner as for a tube obstruction.

In order to make these tests it is necessary to have suitable test points on the tubes. At least one such point is provided on all London street tubes and where the tubes run through manholes, pavement boxes, subways and other accessible positions additional test points are available. This naturally simplifies the tests especially in regard to leak faults as the variation in the pull in the string is less easily detected after 400 or 500 yards have been run out.

Promotion.

Mr. W. Day has been promoted to Executive Engineer and transferred to Gloucester. During his period of service in the London Engineering District Mr. Day made many friends and he carries their good wishes with him to his new sphere. Mr. Day will be greatly missed at Institution meetings, Debating Societies and other places where men gather to speak.

Visit to America.

The Superintending Engineer of the London Engineering District is now in the United States where he is examining the methods of providing telephone plant and other matters relating to telephones.

Voice Frequency Key Sending from "A" Positions.

An experimental equipment for a new method of key sending from the "A" positions at manual exchanges direct into the switches at automatic exchanges has been installed at Clerkenwell manual exchange to work into National automatic exchange.

This method uses voice frequency currents of four different frequencies within the range of 425 to 935 cycles per second, for transmitting coded pulses over the junction loop. The frequencies are used either singly or in combinations to obtain the code equivalent of the numerical digit 1–0.

The voice frequency currents are received at the automatic exchange on reed tuned relays, designed and manufactured by the Standard Telephone and Cables Company, one relay being provided for each frequency.

The operation of these relays either singly or in combination operates in turn a sender of the standard 4-digit type in a similar manner to the operation of the sender direct from a digit key on a key sender "B" position. The experimental equipment has been installed at five "A" positions at Clerkenwell from which public traffic is routed over junctions worked on the straightforward method into the senders and selectors at National.

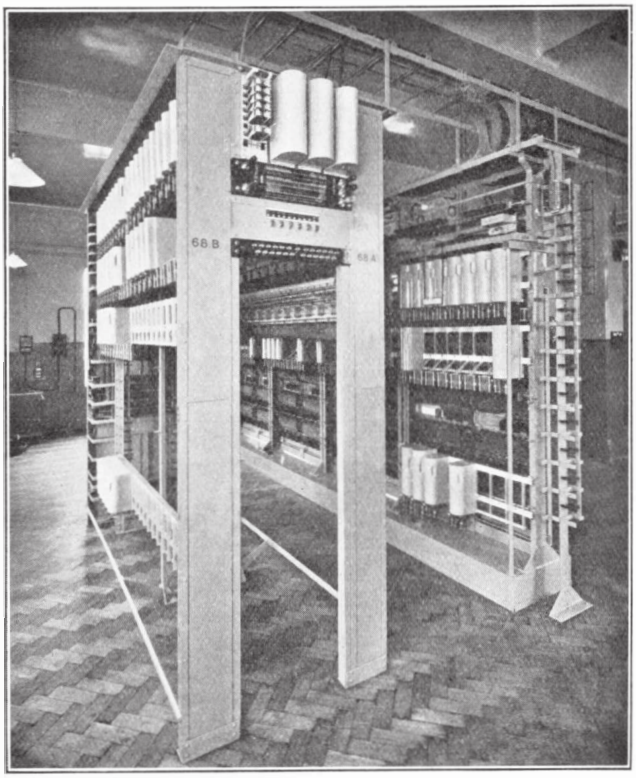
Very satisfactory results have been obtained. Calls completed at the first attempt with the new method have averaged 87.8%.

NORTH MIDLAND DISTRICT.

Four New Strowger Satellite Exchanges for Nottingham.

It was two and a half years ago that Nottingham Telephone subscribers were first inducted into the benefits of Automatic Dial Telephones with the official cut-over of new Automatic exchanges at Central, Sherwood, Arkwright Street, and Basford, totalling 12,500 lines.

These four exchanges were equipped for the British Post Office by Automatic Telephone Manufacturing Company Ltd., Strowger Works, Liverpool, and to them have now been added



Arnold Satellite Exchange: Nottingham.

four additional Strowger satellite exchages—Arnold, Beeston, Bulwell, and Carlton, equipped by the same Company.

All four exchanges are designed to operate on the 5-digit system, and are equipped with homing rotary lineswitches, and discriminating selector repeaters.

The respective capacities are as follows:—

	Present.	*Ultimate.*
Arnold	500	1400
Beeston	900	3000
Bulwell	600	1400
Carlton	700	2100

All four are satellites to the Main or Central Exchange, the principle of operation being as follows:—

When a subscriber removes his receiver preparatory to dialling he operates the associated line relay. This, in turn, immediately rotates the rotary lineswitch from its home position until it locates a contact connecting with a disengaged discriminating selector repeater.

This found, the lineswitch ceases to hunt and the cut-off relay extends the loop to the discriminating selector repeater. Associated with the latter is a junction finder rotary lineswitch which immediately hunts for a disengaged junction to central.

When found, dial tone is automatically returned to the caller, signalising that dialling may commence.

The whole of the foregoing action takes place within the brief period between lifting the receiver and locating the first digit preparatory to dialling.

Dialling the first digit raises two selector shafts simultaneously to the corresponding level, viz., that of the discriminating selector repeater at the local exchange and that of the first group selector associated with the seized junction at Central. The wipers of both switches then automatically rotate; that of the discriminating selector repeater releases, whilst the first selector at Central hunts for an outlet to a disengaged second selector.

Dialling the second digit again operates the discriminating selector repeater, together with the second group selector at Central. Both shafts rotate.

Should the first two digits imply a local call, the discriminating selector repeater will hunt over the corresponding level for a disengaged third group selector in the local exchange. Simultaneously the junction loop to Central is opened, releasing all switches held there.

The call now proceeds in the usual way, the third, fourth and fifth digits dialled operating the third group and final selectors respectively.

Alternatively, in the case of a call for a number associated with another exchange, having reached the stage of the second digit at which both the shafts of the local discriminating selector repeater and of the second selector at Central are stepped to the same level, the former remains in this position, the local switch simply acting as a repeater for the remainder of the digits dialled, which operate the distant third group and final selectors in the usual way.

Removal of his receiver by the called subscriber reverses the battery on the lines between the final selector and the discriminating selector repeater, thereby causing the meter to operate and record the call against the caller.

Should all junctions to central be engaged the junction finder rotary lineswitch will rotate to its 24th contact and dial tone will be returned to the caller. In the event of a local number being dialled, the call will proceed as usual, but in the case of a call for a number on another exchange, busy tone will be returned after dialling the second digit.

In the case of P.B.X. lines, dialling the first number of the group ensures automatic hunting for a disengaged line and ultimate connection and ringing over that line when found.

Enquiries, trunks, phonograms, etc., are handled by manual operators at Central, whose services are enlisted by dialling "O."

Junctions incoming from other automatic exchanges in the area terminate on third selectors in these satellite exchanges, as do also direct junctions from the manual switchboard at Central. Thus the operators can obtain access to any subscriber by dialling three digits only.

The two preliminary digits for each of the four exchanges are: Arnold 68, Beeston 54, Bulwell 78, and Carlton 58.

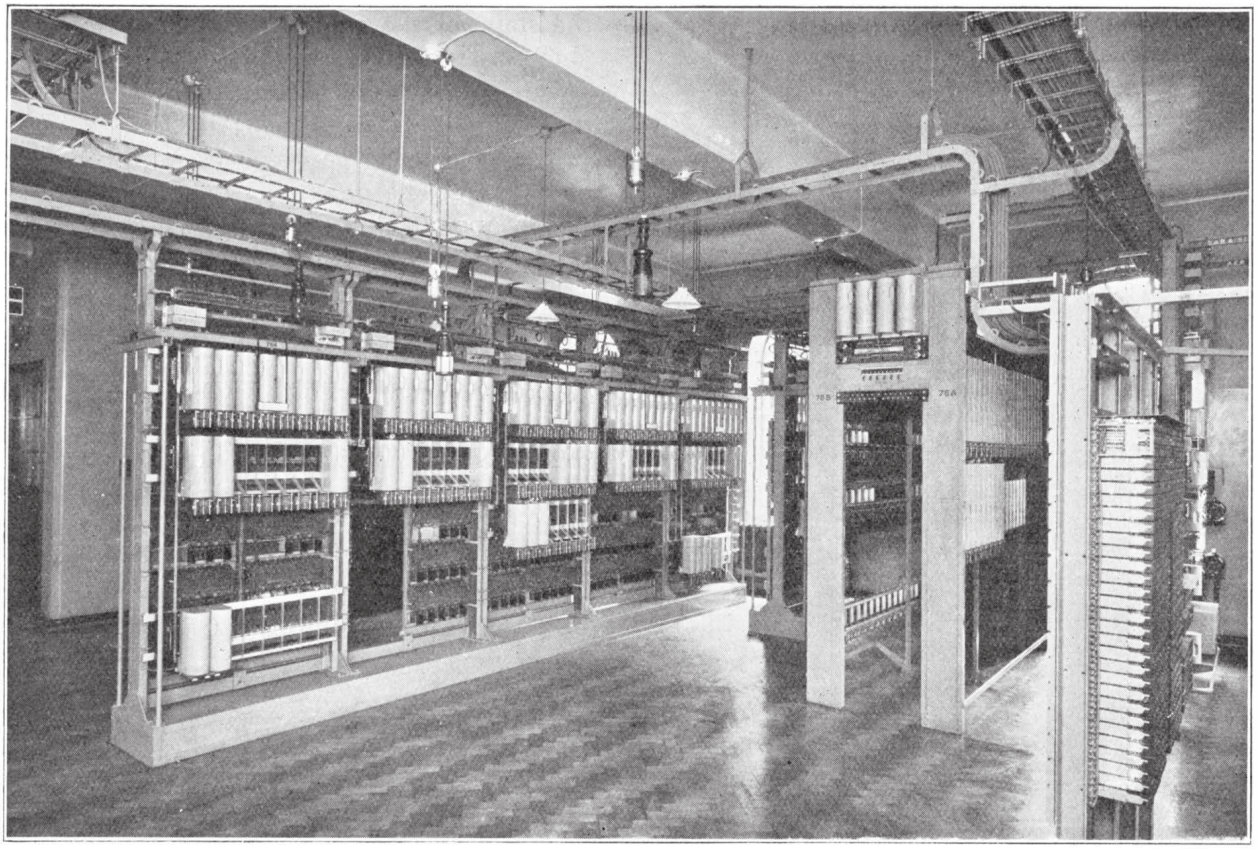
The equipment of the satellite exchanges comprises regular and P.B.X. Lineswitch and Final Selector units equipped to the complement of their respective initial capacities, together with composite trunk boards mounting the dis-

criminating selector repeaters and their associated junction finder lineswitches on the " A " side, and on the " B " side, group selectors and coin box repeaters.

Auxiliary equipment comprises M.D.F., Meter Rack, O.G.P. Link Frame, and Test Jack Frame.

Generators of appropriate output, with voltage regulation between 50 and 67 volts.

Control of this plant is from Generator panels mounting ammeter, voltmeter and multi-way switches facilitating readings at various points; generator field rheostat, S.P. circuit breaker, and the usual charge and discharge switches.



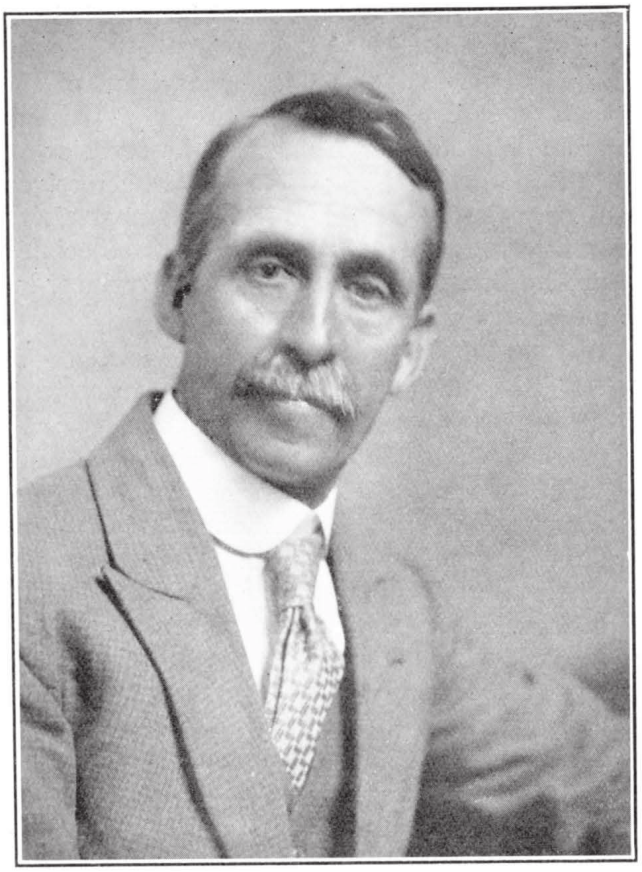
BULWELL SATELLITE EXCHANGE: NOTTINGHAM.

The Power equipments for supplying current to operate the automatic exchange equipment and to energise the subscribers' telephones comprise, in each case, duplicate main batteries of Alton Battery Company manufacture, each battery comprising 25 cells, of an ampere-hour capacity appropriate to the exchange load.

These are kept charged from motor-generator sets, comprising enclosed ventilated squirrel cage motors designed for operating on 400 volts, 3-phase, 50-cycle supply, direct coupled to D.C.

Due provision for future extensions is made in the accommodation for extra battery plates, etc.

The entire equipment of these four new satellite exchanges has been successfully completed by Automatic Telephone Manufacturing Company, Ltd., and they have been placed in service by the Post Office without a hitch. The area now embraces some 15,200 lines. We are indebted to the A.T.M. Co., Ltd., Strowger Works, Liverpool, for the photographs accompanying this description.



Mr. H. Kemp.

Mr. Harry Kemp.

On the 6th of August last, Mr. H. Kemp, Executive Engineer, Coventry, retired after 47 years service. He commenced his career in the Post Office at Manchester, where later, in 1895, he was appointed Junior Clerk in the Engineering Branch, when the total clerical force in the Superintending Engineer's Office was five! In 1899 Mr. Kemp became Sub-Engineer at Preston, proceeding to Bangor as Second Class Engineer in 1902, where he remained for over two years during the period when the Post Office was maintaining the "Wireless" Communications between Cemlyn, in Anglesey, and the Skerries Lighthouse—an arrangement consisting of a line of single wire on each side of the water, each earthed at both ends with a telephone in each, a "Conduction" arrangement in effect, and not over reliable in action. The early experiments in spark operated wireless between the South Stack rock at Holyhead, and Howth, were also being carried on whilst Mr. Kemp was at Bangor.

At the re-organisation in 1904 he was transferred to Chester, and in 1908 was promoted to First Class Engineer at Shrewsbury. Early in 1917 Mr. Kemp took over the Coventry Section, filling the vacancy caused by the death of the late Mr. W. J. Stubbs. At this time, twelve months after the great 1916 Snowstorm, there were still over 300 men engaged in the Coventry Section on line repairs.

Mr. Kemp's official activities were many-sided. He probably built more miles of main lines than the majority of present day engineers and it is an open secret to his old staff that, although he has retired from active service, the location of his home, practically in the heart of his last Section, coupled with the use of a recently acquired motor-car, will cause him to preserve an interested and critical eye,—it is to be hoped for many years—for these small monuments, as it were, to his energy in this field of his work. His Staff rather suspected that Mr. Kemp sometimes regarded the extensive road works of recent times not merely as improvements necessitated by modern traffic, but as Heaven-sent inspirations to prevent the construcion of Main Lines from becoming a lost art!

It is interesting to record that during Mr. Kemp's service in the Engineering Branch, he served under ten Superintending Engineers.

On the 15th August a splendidly attended smoking concert was held at Coventry (a large contingent coming over from the Northampton side of the Section) under the Chairmanship of Mr. A. B. Gilbert, Superintending Engineer, when the presentation was made to Mr. Kemp of a handsome gramophone cabinet and collection of records from his own staff and a number of colleagues throughout the North Midland District.

An excellent musical programme which had been arranged, had to be very materially cut down to provide opportunities for all his colleagues and members of the staff who were keen to voice their appreciation of Mr. Kemp's numerous good qualities, and to wish him good luck and happiness in his retirement. Amongst his hobbies are bowling, billiards and gardening, at all of which he excels, and many hopes were expressed that he would live long to enjoy them.

MR. J. R. M. ELLIOTT.

NORTHERN DISTRICT.

MR. J. R. M. ELLIOTT, M.I.E.E.

Mr. John Robert Maddison Elliott, M.I.E.E., Superintending Engineer, Northern District, retired from the service on the 9th August, 1930. He entered the Post Office service as a Telegraph Messenger in 1883, and after successive appointments as Telegraphist, Relay Clerk, 2nd Class Engineer, 1st Class Engineer, Staff Engineer, and Assistant Superintending Engineer reached the rank of Superintending Engineer at the age of 42 years. Probably no one will gainsay that Mr. Elliott and his contemporaries entered the Engineering Department at a propitious time, but at the same time no one will stint their praise of these men who, without the benefits of modern educational facilities, by self-sacrifice, hard work and determination equipped themselves to discharge with credit and distinction the highest duties in the Department.

Mr. Elliott's service in the Department has been varied and his duties have necessitated his residing in many parts of the country. He has served in Wales, Scotland, London, Headquarters and the Provinces, and has carried out work as far afield as the Orkneys, Shetlands and Channel Islands. For his supervision of the signalling arrangements in London, particularly in Westminster Abbey on the occasion of the coronation of King George V, he received the special thanks of Field-Marshal Lord Kitchener. He was for many years associated with the Telegraph Section of the Engineer-in-Chief's Office.

Mr. Elliott returned to his native town of Newcastle-on-Tyne in 1912 to take charge of the Northern District. His intimate knowledge of the District, and his friendship with the Municipal officials in the area were no doubt of great assistance, but he had excellent administrative ability. Co-operation and helpfulness are nowhere more strongly evidenced than in the Northern District and, whilst this is partly due to most of the supervising officers being local products and more or less contemporary, it is more attributable to the even-handed manner in which Mr. Elliott has administered his District. No class was given preferment, all felt that they received fair treatment, and all worked harmoniously together. It must be said, however, that Mr. Elliott had a leaning towards the junior members of the staff whom he sought to encourage on all occasions, and the I.P.O.E.E. meetings were exploited to serve this purpose. It is an open secret that, whenever possible, junior members opened and occupied the forefront of the discussions.

As Chairman of the Northern Centre, Mr. Elliott took a keen personal interest in I.P.O.E.E. activities. He endeavoured to maintain the interest of all ranks by making the programme as representative as possible and by enlisting the services of lecturers from all the classes comprising the membership. A popular innovation introduced by Mr. Elliott was the provision of light refreshments at the Centre meetings, which met a long felt need in the case of members from the outlying areas, and in these circumstances the meetings served to provide a pleasant means for social intercourse.

Another successful feature introduced by Mr. Elliott was the "Summer Outing." This annual gathering of members, wives and friends

has taken place in the month of July for the last five years, and has been the outstanding social event in the District. No one entered into the spirit of these outings more than "the Governor" and the atmosphere of good fellowship and courteous consideration which contributed so much to the unqualified success of these outings was in great measure due to his influence. The measure of Mr. Elliott's interest in I.P.O.E.E. activities is reflected in the record of 100% membership which the Centre has maintained for a number of years.

If genius be the capacity for taking infinite pains, then J. R. M. Elliott was a genius. His patience was phenomenal. He never tired of detail and when Unit Costing was re-introduced into the Department in 1919 Mr. Elliott came into his own, and was not satisfied until he had evolved a system of definitely ascertaining the cost of maintaining each item of plant at every lineman's centre, with the result that any abnormality in cost could be readily found and remedial measures necessary immediately applied. The system is fully described in his paper "The Control of Labour Costs" (I.P.O.E.E. printed paper No. 94).

No charitable appeal passed Mr. Elliott unnoticed. In his early years he was keenly interested in the Post Office Clerk's Benevolent Fund and this year he had the intense satisfaction of seeing a scheme, initiated by himself, for endowing a bed in the Newcastle Infirmary in the name of the Post Office staff, brought to successful fruition.

His long association with the Northern District made him a well-known personality with the public in matters relating to the Telephone Service, and he was frequently in demand at public functions, and he never lost an opportunity of advancing the Department's interests.

Mr. Elliott will probably admit that his tenure of office in the Northern District has been very happy. His relations with all ranks of the staff, with the Municipal Authorities, and with the public utility companies, have been most cordial. His kindly disposition has endeared him to all he came in contact with, and like Abu Den Adhem he might well say "I pray thee then write me as one that loves his fellow men."

Mr. F. G. C. Baldwin.

Mr. Francis G. C. Baldwin, M.I.E.E.,
Superintending Engineer, Northern District.

Mr. Francis G. C. Baldwin has been appointed Superintending Engineer of the Northern District, as from the 10th August.

Mr. Baldwin was educated at the Modern School, Barnsley, and the Sheffield Technical School. His first appointment was with Messrs. Thos. Nash & Sons, Inspecting and Testing Engineers, Sheffield. He continued his training in Science and Electrical Engineering at the Institution which subsequently became the Technological Department of the Sheffield University.

He entered the service of the National Telephone Company in 1896, and was appointed Engineer at Sheffield in 1899. For several years he officiated as Lecturer and Demonstrator in Electrical Engineering at the evening classes held at the Sheffield Technical School.

In October, 1906, he was appointed District Engineer for Birmingham, which at that time had 26 Telephone Exchanges, approximately 14,000 subscribers and 52,000 miles of wire, of which nearly 40,000 miles was underground. He superintended the first comprehensive scheme of practical commercial line loading (with Pupin Coils) executed in this country.

In September, 1909, he was appointed Assistant Metropolitan Engineer, and when the Inventory of the National Telephone Company's plant was commenced in 1910, he assumed charge as Acting Metropolitan Engineer of the whole of the external plant in the Metropolitan Area under the superintendence of Mr. C. B. Clay. At that time the National Telephone Company's plant in the Area embraced 61 Telephone Exchanges, 141,100 telephone stations and a wire mileage of 293,970.

Mr. Baldwin's first appointment with the Post Office was in London as Sectional Engineer of the City External Section in 1912. In December, 1913, he was promoted to the rank of Assistant Superintending Engineer of the Northern District at the early age of 35 years. Mr. Baldwin was admitted an Associate of the Institution of Electrical Engineers in 1904, became Associate Member in 1906 and Member in 1919. He has served on the committee of the N.E. Centre for a number of years and was the Chairman of the Centre in 1922. Mr. Baldwin is well known as a writer and lecturer and he has read many papers before various Centres of the Institution of Electrical Engineers and the Institution of Post Office Electrical Engineers, of which the following are perhaps the most notable :—

" Some Considerations in the Manipulation of Telephone Dry Core Cables."

" Telephone Exchange Transfers and their Organisation." (Fahie premium awarded).

" The Progress and Potentialities of the Telephone in the United Kingdom."

" Scientific Organisation and the Post Office Engineering Department."

He is the author of " The History of the Telephone in the United Kingdom " (published by Chapman & Hall in 1925), a notable volume in the bibliography of the profession.

In addition he has delivered lectures on such diverse subjects as Geology and Colour Photography.

Due to his 16 years' service in the Northern District as Assisting Superintending Engineer, Mr. Baldwin has an intimate knowledge of the plant and he is personally acquainted with most of the staff, who hold him in high esteem and regard.

Mr. John Robert Andrews, M.I.E.E.

Before the publication of these notes Mr. John Robert Andrews, M.I.E.E., Executive Engineer, Newcastle South Section, will have retired after 48 years' service.

Mr. Andrews rose from the rank of Telegraph Messenger to Executive Engineer and will finish his service in the same town as he began. Although threatened with a serious breakdown in health whilst at Cambridge, his transfer to Newcastle in 1921 effected a wonderful recovery and he will lay aside official responsibilities looking more like a man of 50 than 61 years of age.

Mr. Andrews was a musician of outstanding ability, and as a church organist, choral conductor and pianist he has achieved more than local fame. In his earlier years his musical activities occupied a great deal of his time, but in later years his services have been much more in demand on account of his high office as Chairman of the Freemen of Newcastle-on-Tyne, and his name is a household word on Tyneside. It may be said quite definitely that the Freemen have never possessed a more courageous, progressive or successful leader than J. R. Andrews, and it must also be admitted that never in the history of local politics were the outstanding abilities of such a man more needed in order that the rights and privileges of the public might be adequately safeguarded. No civic function is complete without the presence of J. R. Andrews, and no toast list is satisfied without the fluency, satire, and witticisms which are characteristic of his speeches.

Officially he will probably be best known by his constant endeavour to economise and to keep down costs, and he is proud to recall that since he took over the Newcastle South Section his savings, based on the Provincial Average Cost for Maintenance and on the standard rates for construction costs, have reached a considerable figure.

Mr. Andrews was a fearless administrator, and the patch of carpet in front of his table has a somewhat worn appearance. At the same time any of his staff in difficulties or in distress never hesitated to ask his advice or seek his assistance, because these were always forthcoming and invariably in a very practical and particularly helpful manner.

Mr. Andrews is a man of dynamic energy

and it is perhaps just as well for his health's sake that a commercial concern has already commandeered part of his time when he retires, and that his municipal activities are likely to expand.

A social function is being organised by the Newcastle South Section to bid farewell to Mr. Andrews. When he retires, the Department will lose a zealous servant and the Northern District one of its outstanding personalities.

Summer Outing.

The Summer Outing took place on the 8th July and like its four predecessors was an unqualified success. The party of members and friends numbered 68, and thoroughly enjoyed the visit to Rokeby Park and " the meeting of the waters." The outing was so arranged this year that members in outlying parts of the District were enabled to participate, and under the genial guidance of the Chairman, Mr. J. R. M. Elliott, everybody entered into the spirit of the picnic and spent a happy day.

Mr. G. F. Bellwood, M.I.E.E.

The retirement of George Francis Bellwood, M.I.E.E., Executive Engineer of the Technical Section, has withdrawn a particularly valuable member from the Northern Centre. Only those responsible for the working of the Centre can adequately appreciate the extent of the services rendered to the I.P.O.E.E. by Mr. Bellwood. He has read papers on such subjects as—

" Breakdown Organisation."
" C.B.S. Multiple Exchanges."
" Some practical points in relation to Main Underground Cable work."
" Through Signalling on Trunk and Junction Circuits."
" Central Battery Systems with modifications."
" Trunk Signalling."

His paper on " The Centralisation of Cord Repairs " was printed for unrestricted circulation (Paper No. 91).

In addition to his active personal interest in the I.P.O.E.E. activities, Mr. Bellwood exerted himself to encourage the junior members of the staff to offer papers and join in the discussions, and there are many officers in various parts of the country who will readily admit that their initial participation in I.P.O.E.E. proceedings was due to the practical assistance and encouragement given to them by Mr. Bellwood. Probably no one was better equipped for the role of mentor than Mr. Bellwood. He has taught City & Guilds classes in Telegraphy, Telephony and allied subjects continuously for 22 years and a large number of men of all ranks who have passed through his classes will testify with grateful thanks to the thoroughness, efficiency and patience of his teaching.

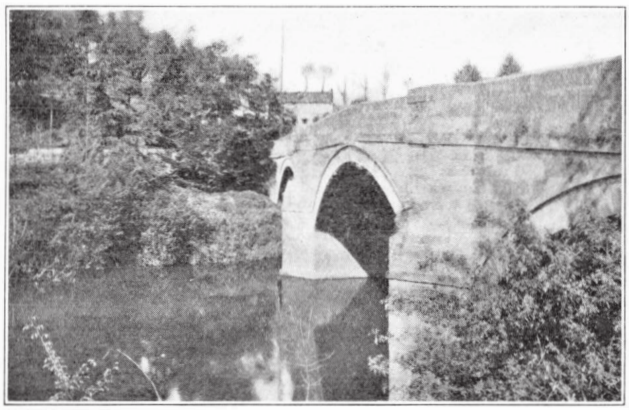
Mr. Bellwood is an energetic personality and although he never spared himself physically or mentally whilst in harness, he leaves the Service with a physical fitness which is the envy of men 10 to 15 years his junior, and only this year spent his holiday on a walking tour.

Before these notes appear Mr. Bellwood will have been presented with some tangible token of the esteem, regard and affection with which he is held by all ranks in the Northern District.

Damage by Floods in North-East Yorkshire.

For several days before the 23rd July last, the people in North-East Yorkshire were very much concerned regarding the threatened damage due to the rising of the rivers through continuous rain. The market town of Stokesley and the villages round the neighbourhood were gradually being flooded through the overflowing of the River Leven. In the main street at Stokesley the water was in some parts nearly waist-deep, and the floor of the Post Office was awash. The water was slowly creeping up the switchboard and the M.D.F., but on the 23rd the " tide " reached its height without doing serious damage.

In the valley of the Esk, however, the Department were not so fortunate, for here, as many visitors to Whitby and its neighbourhood know, the river flows through a narrow picturesque valley. This confined the floods to the course of the river and consequently caused the water to rise very rapidly. There are numerous stone bridges spanning the river between Glaisdale and Whitby, and the arches were soon taking " full bore " and as the floods increased, the weight of water was so great that several of the bridges were unable to stand the pressure any longer. As each bridge gave way, the inevitable rush of water which followed added to the strain already sustained by the others, so that they also gave



SLEIGHTS BRIDGE BEFORE THE FLOOD.

way. One of these was the railway bridge at Grosmont.

The greatest damage came early on the morning of July 23rd, when the bridge carrying the main road at Sleights gave way. This bridge carried the water supply to Whitby and the Department's underground pipe and cables. Just below Sleights the valley widens out towards Ruswarp. Here numbers of picturesque bungalows were flooded to the roof and the gardens were submerged. Ruswarp Bridge, which is an iron structure, stood the strain, allowing the water to pass over it.

The Post Office and Telephone Exchange at Sleights is situated at the end of the bridge on the left bank of the river, and before the bridge broke the water was already pouring into the building.

When the writer arrived on the scene just before noon, the flood had already fallen two feet, but still it was not possible to see any of the masonry of the fallen bridge—the whole was completely submerged. This will give some idea of the depth of the flood.

The cables crossing the bridge carried the junctions from Whitby to Goathland and also the lines to the villages of Grosmont, Glaisdale and Lealholm, so the job on hand was to find out the extent of the damage and restore the service as soon as possible.

An inspection of the cables at the junction box outside the P.O. showed that when the bridge broke it had dragged the cable joints right to the mouth of the duct and severed the lead in both cables, and as this chamber had been under water it was obvious the cable would have to be cut inside the exchange. This was immediately done and the end sealed up. The extent of the damage across the river was not known then, but it was expected that here again the cable would have been dragged and broken at the first joint, which was at a buried coupling, Fig. 1, D.

To the people of Whitby the severing of the water mains was a very serious business. The holiday season was just reaching its height and there were several schools and public institutions where water was a vital necessity and any protracted delay must have led to worse difficulty in sanitation. The local Council had called in the aid of an engineer who was engaged on work in the vicinity. He undertook to get a trestle bridge over to carry new water mains, and an offer was made to the Department which permitted the laying of a new cable across the proposed structure.

This seemed to be an easy way out of the difficulty, but, unfortunately, by the following day, the 24th, very little progress had been made, although the lifeboat rocket crew had been up and " fired " a line across.

It was then decided that the best course to effect a restoration of the telephone service would be to erect a pole on each bank below the broken bridge and take an aerial cable over. During the 24th the water had gone down considerably, so that it was possible to see the masonry of the old bridge in mid-stream.

The contractor got to work and during the night of the 24th-25th managed to get a very temporary bridge across, the operations being illuminated during the night by the powerful

TEMPORARY BRIDGE TO CARRY WATER MAINS, BUILT BY THE R.E's.

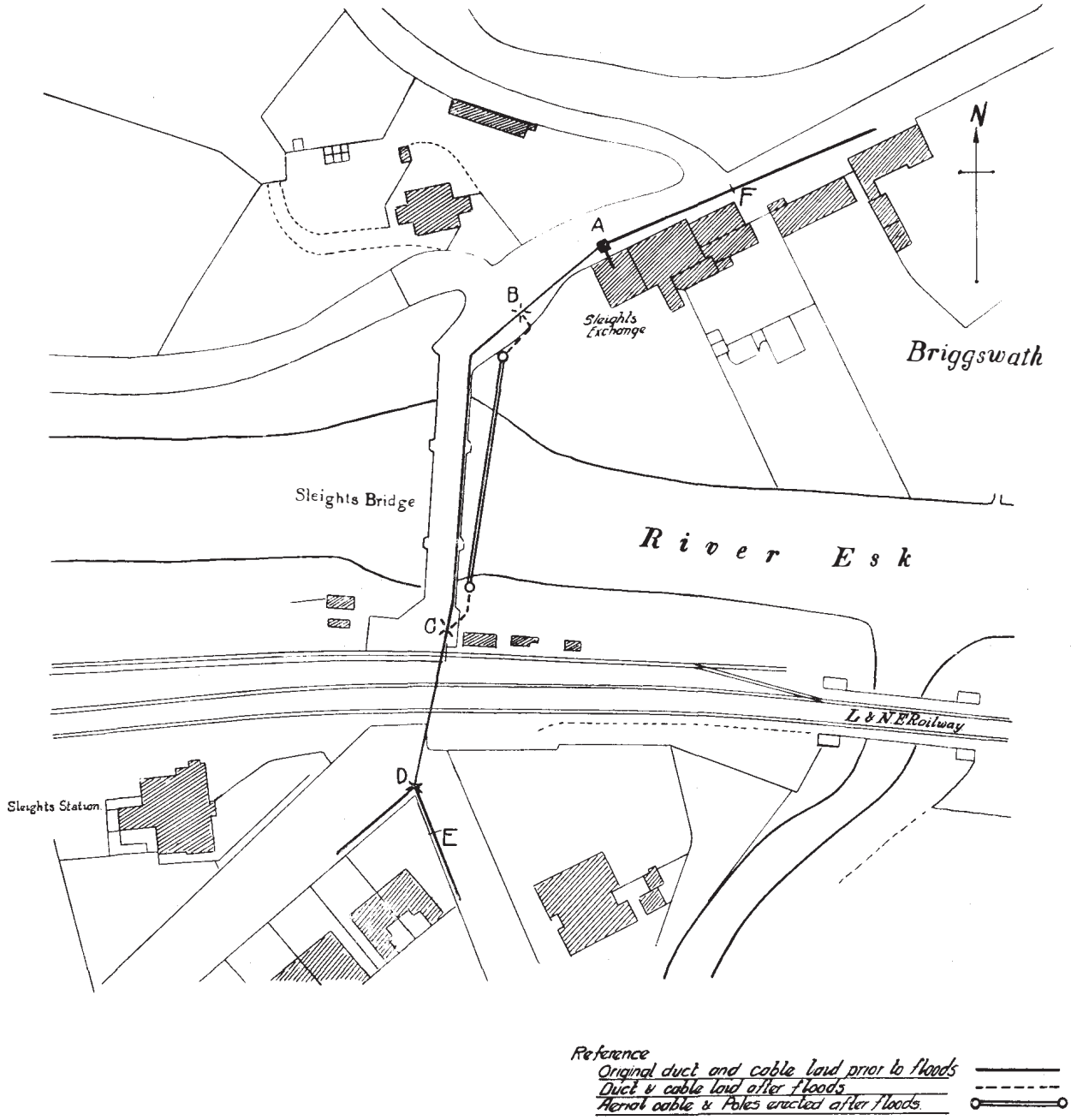


FIG. 1.—CABLE ROUTE PLAN.

head-lights of stationary motor cars. The bridge was constructed mainly of larch trees felled and brought from a plantation nearby, and it was quite an experience walking over it. Peculiar stories have been told of the rope bridge at Carrick-a-Reed, and the sensation caused by its swaying laterally, whilst at the same time one also has the feeling it is rising and falling as a boat on a choppy sea. Similar sensations were experienced here. However, the bridge was a considerable help for the men passing across during operations. The two poles and three steel suspending wires were erected on the 24th and the cable was drawn across, jointed, and all circuits working on the 25th. The sections of cable it was necessary to renew were Fig. 1, F, A, B, C, D, E.

The temporary bridge was not suitable for carrying the water mains, and it was subsequently arranged that the Royal Engineers

should take over the job of strengthening the structure and joining up the water supply. This was done during Sunday, the 27th.

The first photograph, taken from the right bank, shows the bridge before the flood, and the second, taken from the left bank, shows the Royal Engineers busy "consolidating the position" after the water supply was re-connected. The Department's aerial cable is seen to the left of this photograph.

S.B.T.

SOUTH LANCASHIRE DISTRICT.

Mr. A. J. Pratt, M.I.E.E., Sectional Engineer, Liverpool External Section, has been elected Chairman of the Mersey and North Wales (Liverpool) Centre of the Institution of Electrical Engineers, for the Session 1930-31. His address at the opening meeting on October 20th will be given under the title "The development of a Telephone System," and will be illustrated by a cinematograph film.

FEDERATED MALAY STATES.

Extracts from the Annual Report on the Posts and Telegraphs Department for year 1929:—

TELEGRAPHS.

During the year 438,249 telegrams were despatched and 463,492 telegrams were delivered, being an increase of 2.2 per cent. in the number of telegrams despatched and an increase of 2 per cent. in the number delivered, as compared with 1928. The revenue derived from telegrams was $445,398. The revenue shows a decrease of $20,880 or 4.5 per cent. from that of 1928. The value of telegrams sent free of charge for Government Departments was $41,906, a decrease of $8,563.

Keyboard perforators, for use in conjunction with Wheatstone sets, were introduced at one or two of the larger telegraph offices and have proved of value in facilitating the rapid and accurate transmission of telegraph traffic. The use of typewriters for the reception of telegrams was further extended, with satisfactory results.

In conjunction with the Eastern Extension Australasia and China Telegraph Company, Limited, arrangements were again made for the acceptance at any telegraph office in the Federated Malay States of "Christmas and New Year Greeting Telegrams," for a long list of countries, at rates which approximated to one-quarter of the ordinary charges.

The number of countries with which Daily Letter Telegrams are exchanged was added to during the year, and a new service or Week-end Letter Telegrams, at a cost of 25 cents a word, was introduced between this country and Great Britain and Ireland.

TELEPHONES.

The number of direct exchange lines connected to the telephone system on the 31st December, 1929, was 5,075, an increase of 541 as compared with 1928. In addition there were 2,403 miscellaneous circuits, such as extension lines, extension bells, private lines, private bell or alarm circuit and tell tale clock circuits maintained by the Department, as compared with 2,177 in 1928.

The revenue derived from telephones was $1,352,935, an increase of $156,151 over 1928. The junction and trunk revenue amounted to $463,155, an increase of $78,241 over the previous year.

Six new public exchanges were opened for service during the course of the year.

On the 31st December, 1929, 65 public telephone exchanges were in service in the Federated Malay States; 95 public call offices available at post offices and postal agencies throughout the country, and there were 37 applicants waiting for connection to the telephone system; all of these were of recent date.

The average number of originated calls per direct exchange line per day was 12.7, an increase of approximately 12.4 per cent. on the average figure for 1928.

The average total numbers of originated calls per day throughout the Federated Malay States telephone system during the year were:

Local calls 51,740
(increase over 1928, 26 per cent.)

Junction calls 4,960
(increase over 1928, 77 per cent.)

Trunk calls 4,540
(increase over 1928, 5 per cent.)

Total originated traffic... ...	61,240
(increase over 1928, 27 per cent.)	

The approximate total originated telephone traffic during the year was as follows:

Local calls	15,056,000
Junction calls	1,443,000
Trunk calls	1,321,000
Total originated calls ...	17,820,000

Progress was made with the arrangements for the provision of a new exchange of the automatic type to replace the existing Kuala Lumpur Exchange. The contract for the installation of the necessary equipment was placed with Messrs. Ericcsons Telephone Manufacturing Company, Limited, of Beeston, Nottingham, England, in September, 1929. The new building required to house this equipment was well advanced by the end of the year under review.

The " Carrier Current " system of telephony was brought into service between Kuala Lumpur and Ipoh on the 1st June, 1929, providing thereby three additional speech channels between these two exchanges. These channels have worked quite satisfactorily for the period during which they were in service during the year, and effected the much needed improvement required in the speed of service between the exchanges concerned.

The question of providing direct telephonic speech channels between Singapore, Kuala Lumpur and Bukit Mertajam was re-opened during the year with a view to introducing at the end of the year " Carrier Current " working between those exchanges. Definite proposals were made by this Department to both the Straits Settlements and Federated Malay States Governments, for establishing this service as soon as possible. At the end of the year those proposals were still under the consideration of the Governments.

Engineering.

On the 31st December there were 3,084 miles of telegraph and telephone lines and 24,607 miles of overhead wire in the Federated Malay States, of which 21,444 miles were telephone wires. In addition there were 144 miles of underground cables containing 13,100 miles of single wire line. These figures do not include the poles and lines maintained for its own use by the Railway Department. The Posts and Telegraphs Department also owns and maintains 123 miles of line and 611 miles of wire in Johore. It also maintained in 1929 two miles of pole line for Kedah and 1,020 miles of wire for Johore.

The underground system was considerably extended during the year, particularly in the Kuala Lumpur area where, in connection with the installation of the new Automatic Telephone Exchange, a great deal of work was done in rearranging and extending underground cables. The total additional cable laid during the year amounted to 23 miles, giving an additional single wire mileage of over 1,672 miles.

Wireless.

One hundred and nineteen temporary licences for the use of wireless receiving apparatus were issued during the year and three experimental transmitting licences.

The British official news broadcast from the wireless station at Rugby in England, received at Penang Wireless Station and retransmitted from Penang by land-line for delivery to local newspapers on payment of a monthly fee, averaged 22,780 words a month.

The Petaling Hill Wireless Station in Kuala Lumpur was practically rebuilt in the course of the year, and a half kilowatt short-wave set was installed there on a permanent basis. A store, workshop and quarters for the operating staff have been built on the site. This station is now in daily communication with the various wireless stations in Pahang.

As part of the Flood Emergency Scheme, wireless stations were maintained throughout the year at Kuala Pahang, Kuala Lipis, Kuantan, Mentakab and Temerloh. Whenever the land-line to Kuantan is interrupted, telegraph traffic between Kuala Lumpur and Kuantan is disposed of by means of wireless; and the normal route for telegraph traffic between the Federated Malay States and Trengganu is now *via* the Kuala Lumpur and Kuantan wireless stations.

A wireless station, equipped with a half kilowatt set, was opened at Port Swettenham on the 1st April, for communication with ship stations. It was maintained in satisfactory operation up to the end of the year.

Two low-power medium-wave wireless stations were erected for the Police Department, one at Port Swettenham and the other at Pulau Ketam, to provide telephonic communication beween these two places.

CURRENT LITERATURE.

The Journal of the Institution of Electrical Engineers, Vol. 68, No. 402, June, 1930.

Instrument Transformers. J. G. Wellings and C. G. Mayo. Deals in a general way with the whole field of instrument transformer work, as far as power work is concerned.

An Investigation of Earthing Resistances. P. J. Higgs (from the N.P. Laboratory). The phenomena of polarisation and endosmose were investigated. Earthing resistances of small electrodes depend directly on the resistivity of the surrounding soil. Some electrodes of extensive area, viz., water pipes, lead sheath of a large cable and steel structures were also tested. The smallest resistance obtained was that of a water pipe. The differences between A.C. and D.C. measurements were investigated.

A Thermionic Valve Potentiometer for Audio Frequencies. W. P. Stuart. A description is given of a method of measuring audio-frequency potential vectors with the aid of valves. A method of estimating the admittance between the input potential terminals is described.

An Accurate Method of Testing Bent Permanent Magnets. C. E. Webb and L. H. Ford (from the N.P. Laboratory). The application of the search coil method of measuring H to the testing of bent magnets by the use of jointed coils is fully described.

Vol. 68, No. 403, July, 1930.

Recent Developments in the Protection of Three-Phase Transmission Lines and Feeders. T. W. Ross and H. G. Bell, M.Sc.Tech. Difficulties and methods of overcoming them are discussed and methods of Protection reviewed.

Some Developments of the Piezo-electric crystal as a Frequency Standard. H. J. Lucas. Some observed errors in quartz resonators are dealt with. The use of the improved crystal as a control element in a valve-maintained source of oscillations. A complete calibration equipment of a multi-vibrator system with a range of 1-6000 kc in steps of 1 kc per second is shown.

A New Null Method of Testing Instrument Transformers and its Application. G. F. Shotter. Paper describes some of the common methods and that of the author.

Some Accessory Apparatus for Precise Measurement of Alternating Current. R. S. J. Spilsbury, B.Sc., and A. H. M. Arnold, Ph.D. (from the N.P. Lab.). Paper describes apparatus for obtaining for purposes of measurement a voltage proportional to, and in phase with, a given alternating current.

Precise Testing of Current Transformers. A. H. M. Arnold, Ph.D. (from the N.P. Lab.).

An Analysis of Heating Tests on Electrical Machines. Edward Hughes, Ph.D., B.Sc.

Determination of the Final Temperature-Rise of Electrical Machines from Heating Tests of Short Duration. Edward Hughes, Ph.D., B.Sc.

Vol. 68, No. 404, August, 1930.

The Jet-Wave Rectifier: The Experimental and Theoretical Basis of its Design. Prof. Jul. Hartmann, Dr. Tech. Paper describes the device, a purely mechanical one for high-power rectification.

The Nature and Extent of the Oscillations produced in a Rotary Convertor on Fluctuating Loads and on Short Circuit. H. Cotton, D.Sc.

The Production of Uniform Illumination over Large Areas. H. R. S. McWhirter, B.Sc. (Eng.).

Hysteresis Measurements on Straight Bars and Strips. C. E. Webb, B.Sc., and L. H. Ford, B.Sc. (from the N.P. Lab.). A companion of results obtained by using search coils on bars and strips with those for rings of similar material shows good agreement when compensating magnetising windings are employed at each point on the loop. A drum controller to perform the switching operations is described.

An Investigation of the Frequency Variations in Induction Watt-Hour Meters. A. E. Moore, M.Sc., Tech., and W. T. Slater, M.Sc., Tech.

Some Developments of the Thermionic Voltmeter. E. B. Moullin, M.A. The paper describes the various ways in which a 3-electrode valve should be used in a thermionic voltmeter.

Recent Developments in Direction-Finding Apparatus. R. H. Barfield, M.Sc. Describes (1) a 4-aerial direction-finding system erected near the Radio Research Station, Slough, and

(2) two distinct types of portable short wave direction-finding apparatus.

Journal of the American Institute of Electrical Engineers.

Vol. XLIX., No. 6, June, 1930.

1928 Lightning Experience on 132 Kv Lines of the American Gas and Electric Coy. Philip Sporn.

Voltage Irregularities in D.C. Generators. J. T. Fetsch.

Co-ordination of Insulation as a Design Problem. G. D. Floyd.

Development of a 2-wire Supervisory Control System with Remote Metering. R. J. Wensley and W. M. Donovan. Automatic telephone relays are used.

Recording Fast Transient Phenomena with Cathode Ray Oscillograph in Free Air as well as in High Vacuum. M. Knoll. An available method for taking photographs outside the vacuum was found to be the employment of an electron permeable window (Lenard window) of the size of the oscillogram to be made.

A New Transmission Line Construction. Post Type Towers. Percy H. Thomas. Describes modern power line construction methods.

Transformer Ratio and Differential Leakage of Distributed Windings. R. E. Hellmund and C. G. Veinott. Paper develops the necessity for the concept of " differential leakage " where transformer action takes place between two unequally distributed windings.

Vol. XLIX., No. 7, July, 1930.

An Electron Tube Telemetering System, Parts 1 and 2. A. S. Fitzgerald. Paper describes a varying frequency telemetering system, which is not limited to electrical readings but may readily be applied to any deflection instrument. The accuracy is not affected by changes in the impedance of the channel of transmission and is equally suitable for wire conductors, carrier or radio.

Dancing Conductors. A. E. Davison. The phenomenon of vibrating cables is discussed. Much experimental work has to be done before definite conclusions as to causes can be reached.

Radio Telephone Service to Ships at Sea. William Wilson and Lloyd Espenschied. Paper discusses the American end of the ship-to-shore radio telephone system and also that on the Leviathan.

Rural Line Construction in Ontario. R. E. Jones. A rural power distribution scheme of about 6,000 miles in operation.

The Transmission Characteristics of Open-Wire Telephone Lines. E. L. Green. Values of the primary transmission constants are presented and the factors that govern these in practice are discussed. Data are given for a frequency range from 0 to 50,000 cycles.

Vol. XLIX., No. 8, August, 1930.

Annual Reports of Technical Committees: Power Transmission and Distribution; Protective Devices; Electric Welding; Application to Marine Work; Automatic Stations; Power Generation; General Power Applications.

Long Distance Cable Circuit for Program Transmission. A. B. Clark and C. W. Green. A system of cable networks has been developed and given a trial on a looped-back circuit 2,200 miles long. It transmits ranges of frequency and volume somewhat in excess of those handled by the open wire-circuits now used for program work and also in excess of those handled by present-day radio broadcasting systems when no long distance lines are involved.

A New Portable Oscillograph. Claude M. Hathaway. A portable oscillograph, designed by the G.E.C., Schenectady, simple in operation and is of particular value to scientific and engineering schools.

Mutual Impedances of Ground Return Circuits. Some experimental studies. A. E. Bowen and C. L. Gilkeson. Some of the results of the work of the Joint Development and Research Sub-Committee of the National Electric Light Association and Bell Telephone System on the mutual impedances of ground return circuits.

Rationalisation of Transmission Insulation Strength. Part II. Philip Sporn.

Two-Way Television. Part I. Image Transmission System, Part II. Synchronisation, Part III. Sound Transmission System.

BOOK REVIEWS.

" Alternating Current Bridge Methods." By B. Hague, D.Sc. (Lond.), Ph.D. (Glas.), D.I.C., A.C.G.I., M.I.E.E., M.A.I.E.E., F.P.S.L. Second Edition. 391 pages. Sir Isaac Pitman & Sons, Ltd. Price 15/- net.

The author has revised and enlarged the previous edition. The book deals with fundamental principles, description and theory of apparatus, classification of bridge networks, as well as the choice of a bridge method for specific measurements and the necessary precautions to be taken. As in the first edition, the scope of the work is limited to the consideration of measurements up to several thousand cycles per second only.

The star-mesh transformation theorem is used with advantage in the chapter dealing with the symbolic theory of alternating currents. In the later chapters of the book little more consideration has been given to impurity effects in mutual inductances, and to the effect of earth capacities in standard condensers, than formerly. Screening problems are dealt with briefly, but there is room for a fuller discussion of those cases where elaborate screening arrangements are necessary.

The references given throughout the text and the bibliography, which enhanced the value of the first edition of the book, have been continued and extended in the present edition.

" Definitions and Formulæ " for Students (Electrical Installation Work). By F. Peake Sexton, A.R.C.S., A.M.I.E.E., M.I.E.I. Published by Sir Isaac Pitman & Sons, Ltd. Price 6d. net.

This little book of 26 pages contains many tables and formulæ useful for those engaged on electrical installation work. The definitions, due to the size of the booklet, are brief but useful.

" A Study of the Induction Motor." By F. T. Chapman, D.Sc. (Eng.), Lond., M.I.E.E., A.M.I.C.E. 289 pp. Published by Messrs. Chapman & Hall. Price 21/-.

The author has dealt very fully with the subject with the exception of commutator motors which have been omitted to keep the book within reasonable limits.

Special attention has been given to the harmonic analysis of the air-gap field in developing the theory of the induction motor and it is shown that generally the fundamental field alone is of any practical importance in the transfer of power across the air-gap. From this the author derives a new definition of the dispersion coefficients of the windings, and develops methods for their calculation. In developing the fundamental equations an assumption is made that the magnetic circuit may be replaced by a smooth stator and rotor with iron of infinite permeability, the length of the air-gap being corrected to allow approximately for the slots and the saturation of the iron. The effects of these are investigated fully later.

Separate chapters are devoted to single phase, synchronous, squirrel cage, and multispeed motors: also to motors connected in cascade and the Hunt motor. Finally practical calculations are given showing the application of the methods which have been developed in the earlier chapters.

The book is well arranged and illustrated, and should appeal more especially to designers, engineers and senior students interested in the more advanced theory of the induction motor.

J.McG.

" Post Office Engineering Department Technical Instructions." Published by His Majesty's Stationery Office, Adastral House, Kingsway, London, W.C.2.

Readers of the Journal will be interested to know that a very comprehensive series of Technical Instructions has been issued during the past twelve months. The titles and prices of the separate publications are given below:—

Technical Instructions XXV.
Automatic Telephone Exchange Systems.

Part 4. The Non-Director system.
Text 6d. Diagrams 6d.

Part 5. Siemens No. 16 system.
Text 4d. Diagrams 1/-.

Part 6A. The Director system. System H.
Text 6d. Diagrams 6d.

Part 6B. The Director system. System W.
Text and Diagrams 3d.

Part 6C. The Director system. System C.
Text and Diagrams 3d.

Part 6D. The Director system. System S.
Text and Diagrams 4d.
Part 6E. The Director system. System E.
Text and Diagrams 3d.
Part 8. P.B.X. Final Selectors.
Text 6d. Diagrams 1/-.
Part 13. Traffic Recording.
Text and Diagrams 6d.
Part 14B. Rural Automatic Exchanges.
Text and Diagrams 9d.

Technical Instructions XXXII.
Subscribers' Circuits and Apparatus.
Part 1. Fundamental Circuit Arrangements.
Text and Diagrams 1/-.
Part 3. Party Lines.
Text 9d.

Technical Instructions XXXIV.
Public Exchange Conversions.
Part 3. Conversion of Subscribers Apparatus to Automatic Working.
Text 2/6.

Technical Instructions XXV, Part 4, describes the Strowger step-by-step system for Non-Director exchanges and gives full details of the circuit operation which takes place on a local call for each one of the different types of exchange equipment installed by the various contractors.

Part 5 gives a description of the fundamental principles of the Siemens No. 16 system together with an outline of the circuit operation of various classes of calls.

Part 6A opens with a general description of the principles of the Director system and concludes with a detailed description of the operation of typical circuits employed in exchanges installed by the Automatic Telephone Manufacturing Company.

Parts 6B, 6C, 6D and 6E give circuit descriptions of the Director apparatus installed by Messrs. Standard Telephones and Cables, General Electric Company, Siemens Brothers Brothers and Ericssons respectively. These parts are supplementary to Part 6A.

Part 8 provides an exhaustive description of the various final selector arrangements adopted to cater for groups of P.B.X. lines.

Part 13 describes the various means adopted for recording the traffic flowing through automatic exchanges. The facilities provided for traffic metering are described in an appendix.

Part 14B gives a detailed description of the Unit, Auto, No. 5 which is installed in Rural Automatic Exchanges. Details relating to the installation and maintenance of the equipment are given and the operation of the circuits employed is described.

Students of Automatic Telephony should find these parts, particularly Parts 4, 5, 6A, 8, 13 and 14B, exceedingly useful in assisting to an understanding of this subject which forms an ever increasing aspect of the duties of a Post Office engineer.

Technical Instructions XXXII, Part 1, describes the principles employed in the circuits of subscribers apparatus required for direct exchange lines connected to common and local battery systems. Part 3 describes the circuit arrangements and the method of operating both 2-party lines and rural party lines.

The list of the titles of the various parts into which this instruction is sub-divided, given on page 2 of each part, holds out the promise of providing the student of telephony with a very complete text-book on the subject of subscribers' apparatus.

Technical Instructions XXXIV, Part 3, sets forth details of the scheme employed for the conversion of subscribers' apparatus to automatic working.

The conversion of exchanges from one system to another takes an important place in the work of the Post Office Engineering Department and the list, on the inside title page, of the titles of the various parts of this instruction indicates that when the whole of the parts are published they will form a valuable addition to the technical library of the Post Office engineer.

The Technical Instructions set a fine standard of reproduction and the photographs and diagrams used by way of illustration are particularly clear.

Civil Servants will be interested to learn that Mr. Samuel McKechnie, the editor of the "Civil Service Arts Magazine," has written a book, which will be published next month, entitled "The Romance of the Civil Service."

This interesting volume deals with all the main activities of this vast organisation, and Mr. Philip Snowden has provided a foreword.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	Grade.	Promoted to	Date.
King, R. T.	Executive Engineer, E.-in-C.O.	Assistant Staff Engineer, E.-in-C.O.	14-11-30
Edgerton, T. H.	Executive Engineer, London District.	Assistant Suptg. Engineer, London District.	20-11-30
Hunter, H. J.	Executive Engineer, S. Wales District.	Assistant Suptg. Engineer, S. Wales District.	1-9-30
Jack, J. A.	Assistant Engineer, Scot. West District.	Executive Engineer, Northern District.	To be fixed later.
Stone, A. E.	Assistant Engineer, London District.	Executive Engineer, London District.	1-10-30
Peck, H. G. S.	Assistant Engineer, E.-in-C.O.	Executive Engineer, London District.	20-11-30
Stanton, J. D.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	14-11-30
Balchin, G.	Assistant Engineer, E.-in-C.O.	Executive Engineer, S. East District.	13-11-30
Atkins, W.	Assistant Engineer, S. Mid. District.	Executive Engineer, Northern District.	To be fixed later.
Darke, J.	Assistant Engineer, E.-in-C.O.	Executive Engineer, N. Mid. District.	31-8-30
Linsell, F. A.	Assistant Engineer, S. Mid. District.	Executive Engineer, N. East District.	To be fixed later.
Jarrett, E. J.	Assistant Engineer, N. Wales District.	Executive Engineer, Northern District.	To be fixed later.
Ogden, E.	Assistant Engineer, S. Wales District.	Executive Engineer, S. Wales District.	To be fixed later.
Glover, D. W.	Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	22-7-30
Young, D.	Chief Inspector, S. Mid. District.	Assistant Engineer, S. Mid. District.	To be fixed later.
Wood, G. E.	Chief Inspector, London District.	Assistant Engineer, London District.	18-6-30
Gardner, A. J.	Chief Inspector, London District.	Assistant Engineer, E.-in-C.O.	18-6-30
Bagley, T.	Chief Inspector, N. Mid. District.	Assistant Engineer, Scot. West	To be fixed later.
Hargreaves, T.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Hazlewood, H. A. S.	Skilled Workmen, Class I. E.-in-C.O.	Inspector, E.-in-C.O.	9-12-28
Trussler, H.	Skilled Workmen, Class I., E.-in-C.O.	Inspector, E.-in-C.O.	21-7-29
Thomas, H. C.	Skilled Workmen, Class I., E.-in-C.O.	Inspector, E.-in-C.O.	3-11-29
Findlay, W.	Skilled Workmen, Class I., Rugby Radio Station.	Inspector, Rugby Radio Station.	5-1-30
Middleditch, E. G. H.	Skilled Workmen, Class I., Portishead Radio Station.	Inspector, Leafield Radio Station.	To be fixed later.
Pocock, D. G.	Skilled Workmen, Class I., Rugby Radio Station.	Inspector, Rugby Radio Station.	6-6-30
Thomas, C. F.	Skilled Workmen, Class II., St. Albans Radio Station.	Inspector, St. Albans Radio Station.	13-6-29
Lane, A. E. R.	Skilled Workmen, Class I., Testing Branch.	Inspector, Testing Branch.	24-1-29
Durston, E. A.	Skilled Workmen, Class I., S. West District.	Inspector, S. West District.	5-7-30
Wright, A. R. T.	Skilled Workmen, Class I., S. West District.	Inspectors, S. West District.	13-7-30
Treglown, P. G.			24-8-30
Hoare, J. H.			17-6-30
Marsden, B.	Skilled Workmen, Class I., N. Mid. District.	Inspector, N. Mid. District.	20-5-28
Chadwick, J.	Skilled Workmen, Class I., S. Lancs. District.	Inspector, S. Lancs. District.	To be fixed later.
Brown, R.	Skilled Workmen, Class I., Scot. West District.	Inspector, Scot. West District.	16-8-30

DEATHS.

Name.	Rank.	District.	Date.
Johnson, E.	Chief Inspector.	London.	7-8-30

RETIREMENTS.

Name.	Rank.	District.	Date.
Elliott, J. R. M.	Superintending Engineer.	Northern.	9-8-30
Roach, C. G.	Asst. Superintending Engineer.	S. Western.	31-7-30
Best, F. W.	Asst. Superintending Engineer.	N. Wales.	31-7-30
Haynes, J. H.	Asst. Superintending Engineer.	S. Wales.	31-8-30
Stuart, D.	Assistant Staff Engineer.	E.-in-C.O.	9-7-30
Smith-Bunney, T.	Executive Engineer.	London.	30-6-30
Nichols, A. R.	,, ,,	N. Mid.	31-7-30
Scott, W.	,, ,,	S. Wales.	31-7-30
Bellwood, G. F.	,, ,,	N.	30-6-30
Andrews, J. R.	,, ,,	N.	31-8-30
Tattershall, C. E.	,, ,,	London.	30-9-30
Kemp, H.	,, ,,	N. Mid.	6-8-30
Harrison, W. L.	Assistant Engineer.	London.	31-7-30
Pittman, W. C.	,, ,,	N. Mid.	20-7-30
Stiles, W. E.	Chief Inspector.	London.	29-6-30
Houchin, R. E. H.	,, ,,	S. Mid.	21-6-30
Booth, R.	,, ,,	S. Lancs.	30-6-30
Winter, J.	,, ,,	N. Ireland.	15-8-30
Harrison, G. H. W.	Inspector.	S. West.	16-6-30
Corke, H. J.	,,	S. Lancs.	26-5-30
Doubrowsky, N. J.	,,	London.	30-6-30
Jennings, N. J.	,,	London.	30-6-30
Anderton, W. H.	,,	S. East.	13-7-30

APPOINTMENTS.

Name.	From	To	Date.
Richards, C. E.	Probationary Assistant Engineer, Research Section, E.-in-C.O.	Assistant Engineer, Research Section, E.-in-C.O.	22-7-30
Haliburton, F. C.	Probationary Inspector, N. Mid. District.	Inspector, N. Mid. District.	1-6-30

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	Grade.	Promoted to	Date.
Robinson, W. D.	Executive Officer, E-in-C.O.	Staff Officer, E.-in-C.O.	17-5-30
Brown, B. M.	Executive Officer, E-in-C.O.	Staff Officer, E.-in-C.O.	5-6-30
Buxton, A. D.	Acting Executive Officer, E.-in-C.O.	Executive Officer, E.-in-C.O.	17-5-30
Wilson, P. A. V.	Clerical Officer, E.-in-C.O.	Executive Officer, E.-in-C.O.	5-6-30
Murray, C. E.	Clerical Officer, E.-in-C.O.	Acting Executive Office, E.-in-C.O.	5-6-30
Edwards, A. W.	Clerical Officer, London District.	Higher Clerical Officer, London District.	1-7-30
Chubbock, J. H.	Clerical Officer, London District.	Higher Clerical Officer, London District.	
Shorter, A. E.	Clerical Officer, S. Mid. District.	Higher Clerical Officer, N. Mid. District.	24-8-30
Anderson, C.	Clerical Officer, S. Lancs. District.	Higher Clerical Officer, S. Lancs. District.	8-8-30
Barratt, D.	Clerical Officer, N. West District.	Higher Clerical Officer, S. Lancs. District.	24-8-30
Ferguson, W. N.	Clerical Officer, N. Wales District.	Higher Clerical Officer, N. Wales District.	1-9-30
Williams, D.	Higher Clerical Officer, N. Wales District.	Staff Officer, S. West District.	1-9-30

RETIREMENTS.

Name.	Rank.	District.	Date.
Morris, G. L.	Higher Clerical Officer.	N. Midland.	7-6-30
Scrafton, C. D.	" " "	N. Midland.	8-7-30
Watson, W. G.	" " "	S. Western.	20-7-30
Claydon, T. A.	" " "	London.	31-5-30
Harris, W. T.	Staff Officer.	S. Western.	31-8-30

I.P.O.E.E. PROGRAMME, 1930-31.

LONDON CENTRE.

1930.
21 Oct. Exhibition of official films.
11 Nov. L. L. TOLLEY.
"Testing of paper for use in Telegraph Systems."
9 Dec. *To be arranged.*
1931.
13 Jan. F. R. PERRIS.
"Secondary Cells."
10 Feb. W. R. TYSON.
"The Equipping of Automatic Exchanges."
10 Mar. H. FAULKNER, M.I.E.E., G. T. EVANS.
"Development in Telegraph Technique as applied to Radio Circuits."
12 May. W. W. N. CHEW.
"Making the most of Automatic Telephone Plant; the development of Traffic Measurement."

Informal Meetings.
1930.
28 Oct. H. S. PATE.
"Auto v. Manual Working, Some comparisons of Costs."
25 Nov. A. F. E. EVANS.
"The Development of Key Sending from "A" positions."
1931.
27 Jan. H. W. FULCHER, A.M.I.E.E.
"Ventilation of Telephone Exchanges."
24 Feb. E. H. SLATTERY.
"Public Wayleaves."
24 Mar. R. T. ROBINSON, A.M.I.E.E.
"Motor Transport."
28 Apr. G. A. BARRATT.
"Superannuation Acts."
Visits :—
Croydon Aerodrome.
Post Office (London) Railway.
Post Office Research Station, Dollis Hill.

S. LANCS. CENTRE.

1930.
13 Oct. T. E. HERBERT, M.I.E.E.
Chairman's Address.
10 Nov. A. J. PRATT, M.I.E.E.
"The development of a telephone system." (Illustrated by cinema film).
15 Nov. W. T. LEEMING, A.M.I.E.E., and H. M. TURNER.
"Maintenance Loads and Costs."
1931.
12 Jan. *To be arranged.*
9 Feb. —
"Manchester Auto Exchanges."
9 Mar. *To be arranged.*
30 Mar. *To be arranged.*

NORTH WESTERN CENTRE.

1930.
E. S. RITTER, M.I.E.E., D.F.H. (*E.-in-C.O.*).
"Picture Telegraphy."
T. F. LEVENS.
"Rural Automatic Exchanges."
A. DIGGLE.
"Rochdale Automatic Exchange—Some special features."
1931.
S. UPTON, A.M.I.E.E.
"Unit Costs—their use in the control of expenditure and as an aid to supervision of works."
W. T. PALMER and E. H. JOLLEY (*E.-in-C.O.*)
"Cable Testing Methods."
Visit to Leyland & Birmingham Rubber Co.'s Works, Leyland.

NORTH MIDLAND CENTRE.

1930.
6 Oct. J. R. MILNES.
(1) "Secondary Cells Maintenance."
(2) "Cable Corrosion."
3 Nov. —
"Teleprinters."
1 Dec. *To be arranged.*
1931.
5 Jan. A. S. RITTER, M.I.E.E., D.F.H. (*E.-in-C.O.*).
"Picture Telegraphy."
2 Feb. Col. A. S. ANGWIN, D.Sc., M.C.T.D., M.I.E.E. (*E.-in-C.O.*).
"The P.O. Radio Telephony Stations."
2 Mar. C. A. CARPENTER.
"Unit Construction Costs."
Visit to Messrs. Ericssons Telephone Works, Beeston.

NORTH WALES CENTRE.

1930.
8 Oct. W. E. RADFORD.
"Electrolysis."
10 Nov. B. LYNN (*E.-in-C.O.*).
"Straightforward Trunking."
10 Dec. —
"Exhibition of official and other films."
1931.
10 Jan. Capt. N. F. CAVE-BROWNE-CAVE, B.Sc., M.I.E.E.
"Some important materials and their characteristics."
13 Feb. G. H. GARRIER.
"Some thoughts on electrons."
13 Mar. R. SHEPPARD.
"The Birmingham Automatic Scheme."

SOUTH MIDLAND CENTRE.

1930.
8 Oct. J. E. TAYLOR, M.I.E.E.
"Maxwell, Heaviside-Einstein."
5 Nov. S. D. PENDRY.
"Economical Construction and Maintenance."
Capt. F. A. LINSELL, M.I.E.E., M.C.
"Trunking in Automatic Exchanges."
1931.
7 Jan. S. MOODY.
"Telephoning Rural Areas."
4 Feb. *To be arranged.*
4 Mar. *To be arranged.*

SOUTH WALES CENTRE.

1930.
— Oct. Visit to Messrs. Lysaughts Steel Works, Newport.
— Nov. W. DAY, M.I.E.E.
"Some notes on the conversion of the London Telephonic network from Manual to Director working."
— Dec. E. A. PEARSON.
"Waste, with general reference to Engineering work and design."
1931.
— Jan. H. C. A. LINCK.
"Construction and operation of Teleprinters No. 3A."
— Feb. S. G. JOSCELYN.
"The Drawing Office and its functions."
— Mar. A. E. TILEY and R. D. FUSE.
"Rural Automatic Exchanges."

SOUTH WESTERN CENTRE.

1930.
14 Oct. D. A. BARRON.
"Revolutionary External construction."
11 Nov. A. BUCKLITSCH.
"Maintenance Works and Costs."
9 Dec. Exhibition of Official films.
1931.
6 Jan. *To be arranged.*
10 Feb. F. V. FORD and R. S. COOPER.
"Four-wire repeaters."
10 Mar. W. T. PALMER and E. H. JOLLEY (*E.-in-C.O.*).
"Developments in relation to cable Testing Methods."

EASTERN CENTRE.

1930.
— Sept. Visit to the Baldock Radio Station.
— Oct. F. GUEST.
"The Southend Transfer."
— Dec. Exhibition of Official films.
1931.
— Jan. F. R. PERRIS (*E.-in-C.O.*).
"Secondary Cells."
— Feb. *To be arranged.*
— Mar. *To be arranged.*

NORTH EASTERN CENTRE.

1930.
14 Oct. J. SHEA.
"Improved Methods of Overhead Construction" with exhibition of official films.
11 Nov. *To be arranged.*
9 Dec. *To be arranged.*
1931.
— Jan. *To be arranged.*
— Feb. R. B. GRAHAM, A.M.I.E.E.
"Notes on the Construction and Maintenance of Rural Auto Exchanges."
— Mar. W. W. B. CROMPTON, A.M.I.E.E.
"Plant Records."

NORTHERN CENTRE.

1930.
— Oct. F. G. C. BALDWIN, M.I.E.E.
Chairman's Address.
— Nov. Capt. N. F. CAVE-BROWNE-CAVE, B.Sc., M.I.E.E. (*N. Wales*).
"Sound and Hearing."
— Dec. THOS. DAVIDSON.
"Rural Automatic Exchanges."
1931.
— Jan. T. RICHARDS.
"Secondary Cells—Installation and Maintenance."
— Feb. W. CLOTHIER.
"Internal Combustion Engines—their use in the P.O.E. Dept."
Visit to Newcastle Automatic Exchange.

SCOTLAND EAST CENTRE.

1930.
— Nov. H. BURGHER.
"Underground development schemes."
— Dec. —
"Short papers and exhibition of official films."
1931.
— Jan. J. PATRICK.
"Free wayleaves."
— Feb. —
"Short papers and exhibition of official films."
— Mar. *To be arranged.*
— Apr. —
"Short papers and exhibition of official films."

SCOTLAND WEST CENTRE.

1930.
6 Oct. R. MACWHIRTER, B.Sc.
"Rectification with special reference to Exchange Battery charging."
3 Nov. H. G. S. PECK, B.Sc. (Hons.), A.M.I.E.E. (*E.-in-C.O.*).
"The Director System in London."
1 Dec. Informal.
Subject and speakers to be arranged.
1931.
2 Feb. Informal.
Subject and speakers to be arranged.
2 Mar. A. THOMSON.
To be decided.
The Official films are also to be shown on various dates above.

N. IRELAND.

1930.
7 Oct. A. J. ARDEN (Post Office Surveyor, Belfast).
"Organisation of the British Post Office Mail Service."
4 Nov. Exhibition of Official Films.
2 Dec. W. S. FRENCH.
"Telephone plan number extensions and local difficulties in connection with."
1931.
6 Jan. A. H. JACQUEST, A.M.I.E.E.
"An introduction to cable balancing."
3 Feb. W. S. KEOWN.
"An investigation into the susceptibility of S.A. Ducts to damage."
9 Mar. E. S. RITTER, M.I.E.E., D.F.H. (*E.-in-C.O.*).
"Picture Telegraphy."
7 Apr. W. S. COLSTON.
"Special underground construction in Belfast."

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THE
Post Office Electrical Engineers' Journal

TELEGRAPH INSTRUMENT ROOMS. ADOPTION OF NEW METHODS.

R. P. Smith and F. T. Cattell.

A DEPARTURE from the standard instrument room arrangements for telegraph circuits in this country has been authorised as a result of recommendations made by a Commission of enquiry into the organisation and methods of working the Telegraphs in America. The "Simon" Commission recommended that all apparatus other than that actually required by the operators should be removed from instrument tables and accommodated in test rooms or other suitable positions. (Incidentally, the suggestion to segregate apparatus other than manipulative units was made by the Engineer-in-Chief as far back as 1923, but its adoption has been postponed for various reasons).

Leeds H.P.O. was selected for an experimental application of the suggestion, and the telegraph instrument room at this office has been completely rearranged. Auxiliary apparatus for Morse and Teleprinter circuits has been mounted on racks, double tables have been introduced, with operating positions face to face. Timing stamps for use on busy circuits, and Vee belt conveyors for collecting received messages have also been installed. These features are new to the telegraph service in this country; a detailed description may be of interest, therefore, and useful in the event of further offices being similarly equipped.

Designs for the racks, apparatus, and riser belt conveyors were prepared by the Engineer-in-Chief and the manufacture of the whole equipment, except the conveyor system, was undertaken by the P.O. Stores Department at Holloway Factory. The re-organisation was completed by the Superintending Engineer early in October.

Initially, rack accommodation for 48 Teleprinter duplex, and five Morse duplex circuits has been provided. Concentrator and Wheatstone circuits are not included in the scheme, in view of the probability of their early inclusion in the Teleprinter or Phonogram programmes.

A space 32′ 6″ × 18′ was made available for the erection of three rows of bays, with a maximum capacity of 72 circuits. Fig. **1** shows the instrument room lay-out as regards segregated apparatus, telegraph test case, instrument tables, and belt conveyors.

The rack mounted apparatus is assembled on unit type bays, measuring 6′ $2\frac{3}{8}$″ × 1′ $8\frac{1}{2}$″. They consist of a frame of channel, 3″ × $1\frac{1}{2}$″ × 5/16″ m.s., fitted with a base of angle, 6″ × 6″ × 7/16″ m.s., drilled $\frac{1}{2}$″ clear to take Lewis bolts for floor fixing. Stays being undesirable on account of appearance, individual bays are drilled $\frac{3}{8}$″ clear and bolted together to give the required degree of stability. Mounting plates of $\frac{1}{4}$″ mild steel,

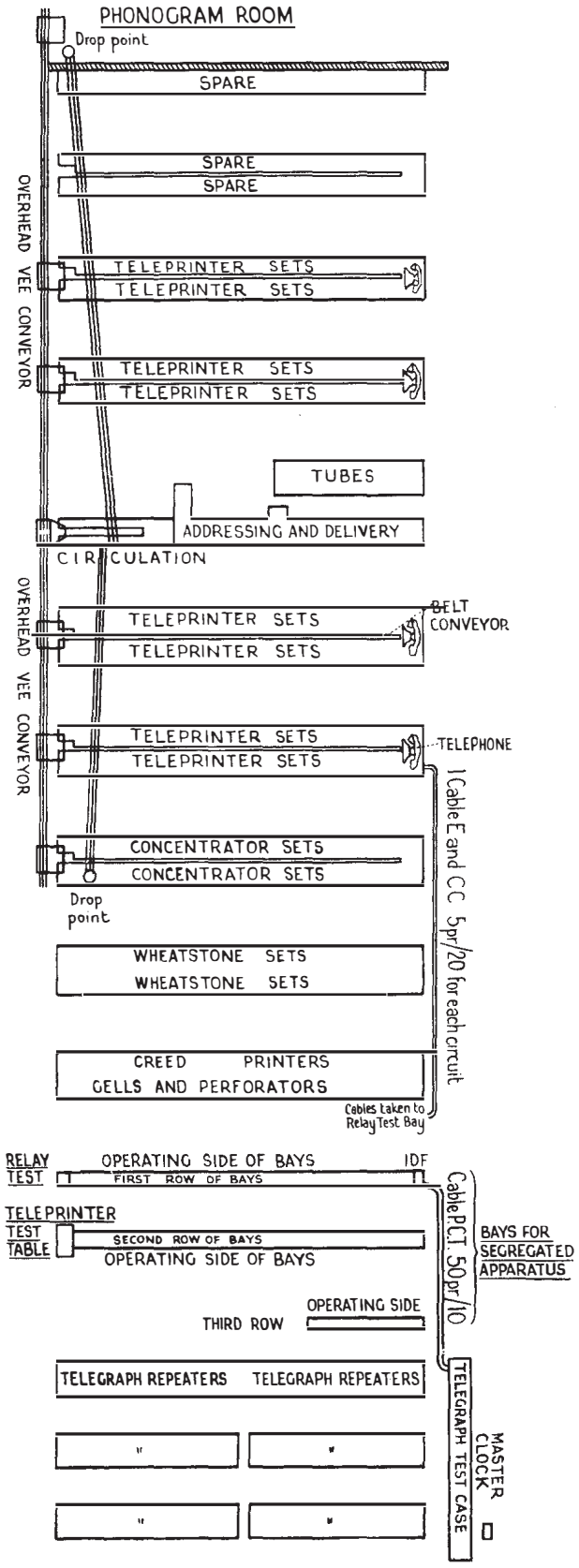


Fig. 1.—Instrument Room Lay-out.

cold rolled, are fitted to the frames by means of Whitworth hexagon head set screws. The plates are spaced to meet the dimensions of the apparatus employed. Fig. **2** shows a unit type bay fitted with apparatus, in position on the concrete foundation.

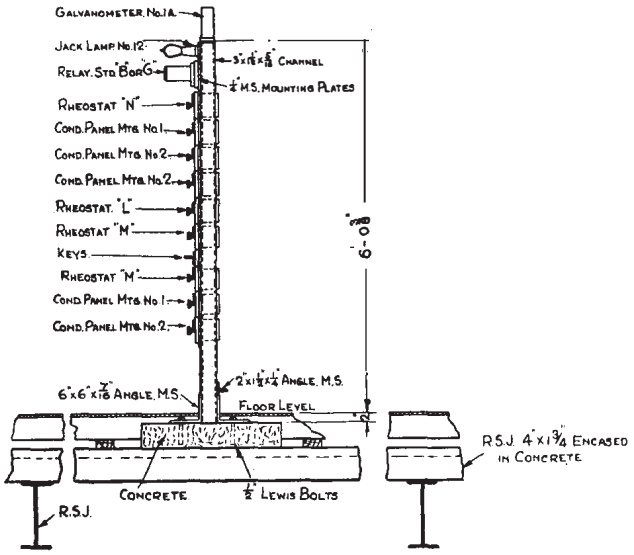


Fig. 2.—Apparatus Bay in Position.

P.O. standard telegraph apparatus is not suitable for vertical mounting as the plugs employed with rheostats, condensers, and other units are liable to be dislodged. Special apparatus having dial adjustment has therefore been designed and, where plugs are necessary, they take the form of a wire U link with one leg tethered. The opportunity has been taken to provide improved condenser units for the duplex balance, giving small gradations in values. The following new items have been introduced:—

Condenser, Panel mounting, No. 1, giving 9.9 μF in steps of 0.1 μF.

Condenser, Panel mounting, No. 2, giving 5.9 μF in steps of 0.1 μF.

Rheostat L, giving 830 ohms in steps of 10 ohms.
,, M, ,, 4350 ,, ,, ,, ,, 10 ,,
,, N, ,, 8430 ,, ,, ,, ,, 10 ,,
,, P, ,, 12430 ,, ,, ,, ,, 10 ,,

Coil Shunt, Panel mounting, giving 14,000 ohms in steps of 2,000 ohms.

The relays employed are of the standard P.O. rectangular base type; they are placed in position by insertion under clips carried by a baseboard mounted vertically on the bay and are therefore

readily removed for adjustment or test. Experiments carried out recently demonstrated that these relays are most sensitive when in a horizontal position with the tongue pointing upwards. This position has consequently been adopted for rack mounting. The weight of an individual bay, complete with apparatus, is approximately as follows:—

Test Bay 272 lbs. Power Bay 300 lbs. Apparatus Bay 252 lbs. The total weight of the racks concentrated upon a small area necessitated the addition of a rolled steel joist to strengthen the floor.

The bays are secured by Lewis bolts to a bed of concrete built up to 2″ below the floor level. Two rows of 17 bays each, and a section of six bays in the third row, were provided in the first instance. A small I.D.F., a relay test bay and a testing table for Teleprinters are also associated with the bays. Excluding the relay test bay three types of bay are provided.

Apparatus Bays. Fig. 3. These accommodate the apparatus for two circuits. A galvanometer of the standard P.O. pattern, connected in the line circuit, is mounted above each apparatus set. It may be turned slightly to give any required angle of vision. Lever keys of the standard type are provided which enable the testing officer to:—

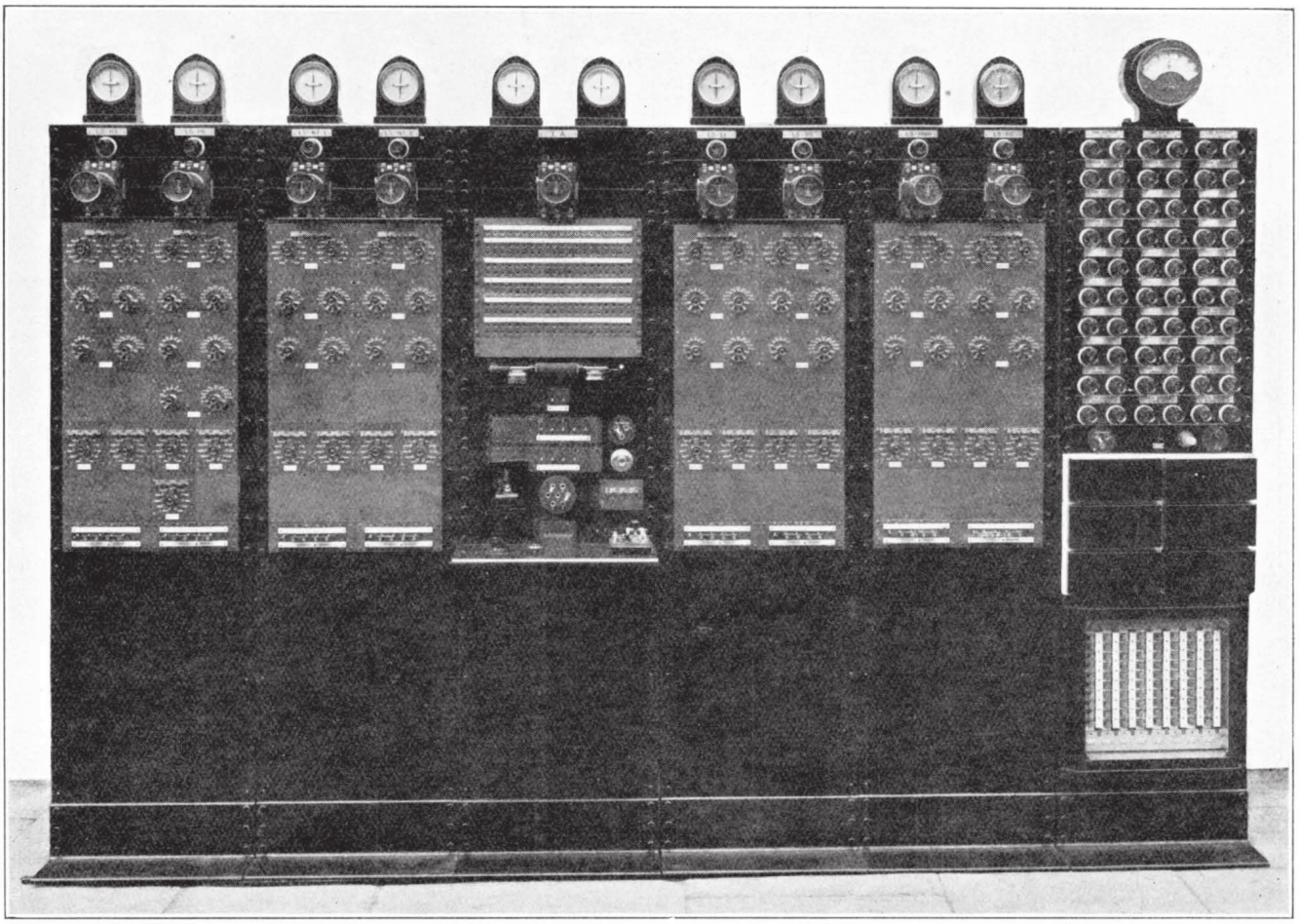


Fig. 3.—Section of Bays. Reading from left: 2 Apparatus Bays, Test Bay, 2 Apparatus Bays, Power Bay.

(*a*) Balance the circuit.
(*b*) Work Morse duplex to the out-station.
(*c*) Work Teleprinter duplex to the out-station.
(*d*) Work Teleprinter duplex to the instrument table.

A key is provided to break circuit between the line relay local battery and the Instrument Table, also a battery cut-off key in the auxiliary circuit

where a relay of the vibrating type is employed.

Power Bays. Fig. **3.** These are provided with jacks for 60 Lamps, Resistance, covering the requirements of 12 circuits. Immediately below the jacks, a small lamp, fuse-mounting and tumbler switch are fitted to form a circuit for testing the 1-amp fuses employed. Cut-outs No. 1 (modified for rack mounting) carrying 10 fuses each, for use with independent batteries and a Cut-out No. 3, accommodating 80 fuses for use with the universal battery supply, are mounted below the lamps where, by means of a plug and cord connection, a change of voltage may be made. Above the bay a centre-scale Voltmeter, reading 150-0-150 volts, is mounted, having connections to a 3-hole tablet fitted on the bay which is paralleled to a similar tablet on the Test bay. At the latter position voltage tests of the universal batteries are made, while loop batteries are tested at the Power bay tablet which is not earth connected.

Test Bays. Fig. **3.** These are equipped with jacks and apparatus enabling any one of eight circuits to be dealt with for testing.

FIG. **4.**—PART OF INSTRUMENT ROOM, SHOWING THREE SECTIONS OF BAYS IN BACKGROUND.

A test bay is placed in the middle of four apparatus bays and associated with a power bay on the right hand side of the group. Fig. **4** shows the first row of bays, comprising three sections, in position. It will be observed that the three tables immediately in front of the bays are occupied by the concentrator and Wheatstone sets not yet replaced. The

apparatus sets are numbered from left to right, A1 to A4 being to the left of a test bay, and A4 to A8 on the right. The number of circuits connected to a test bay is limited to eight to minimise delay should two or more circuits require attention simultaneously, a situation liable to arise when daily tests, prior to opening the circuit, are carried out. A further limiting factor is the distance a testing officer can comfortably reach from the test bay in order to make adjustments of the balancing units on the apparatus bay.

The top jack strip provides jacks for cross connection to other test bays, a 40 volt battery for testing in conjunction with a 7-hole test tablet, and jacks for earth connections. The next four rows have two jack strips of 20 jacks each, coupled; 10 upper and 10 lower jacks are allotted to each Teleprinter to enable tests to be made on the artificial line, A and B lines, " go " and " return " receiving circuit, Teleprinter transmitting line, Teleprinter and line relay batteries. The bottom double jack strip is utilised to provide testing points for the testing apparatus, which comprises a jack to connect the test Teleprinter, socket to connect power for motor, leak galvanometer and relay. A Morse key and a polarised sounder are carried on a fibre-covered wooden shelf projecting 9″ from the bay.

When the testing officer receives an intimation that a circuit requires attention, a Teleprinter mounted on a portable table is wheeled to the position and connected to the jack and plug provided. If the distant office has complained of faulty signals from line, the relative leak key on the test bay is thrown and a duplicate of the signals being sent to line is obtained through a high resistance leak. Faulty transmission would thus become apparent. The circuits include aerial lines, underground screened conductors, underground loops, and earthed circuits superposed on loop circuits, so that the line voltage employed may be as low as 24 v. or as high as 120 v. It is essential therefore that the shunt resistance should vary with the circuit under test and the shunt coil already described is employed for this purpose. If there is difficulty in reception, the test teleprinter is placed in series with the teleprinter at the instrument table by means of a plug and cord connection on the jack strips so that signals from the line relay operates both. A fault may thus be located to the distant station's transmission or to the home station's reception. Incidentally, the arrangement of two teleprinters joined in series demands a high degree of efficiency as regards their adjustment and any weakness in a particular instrument is revealed. Telephonic communication between test bays and the instrument tables for the convenience of supervising officers is provided on the basis of one telephone for each 12 teleprinter circuits. At Leeds this involves provision of a telephone on each double table. To call the testing officer, the telephone is lifted; this causes a lamp and bell on the test bay to give visual and aural warning. The officer answers by operating key switches to join up the telephone set.

The height of the bays was determined by the area required to accommodate apparatus for an underground loop circuit working with a vibrating relay. An apparatus set associated with an aerial circuit requires only five balancing units, an underground loop circuit requires seven, whilst a circuit with a vibrating relay requires seven and four additional units for the vibrating circuit. A minimum height of six feet is required therefore since, with this provision, where a vibrating relay is employed, the lowest unit is only 1′ 4″ from the floor. It is not practicable to reduce this distance, owing to the inconvenience of the position and to the risk of damage to the apparatus by moisture during cleaning operations.

Wire FP, 1 pr/12½, red and blue, is employed for wiring the bays. Connection strips are fitted at the foot of the bays and leads for internal and external connections are taken from this point. Cables from bay to bay are carried on a small shelf made up of angle, 1½″ × 2″ × ¼″ m.s., attached to the frame.

From the bays, five wires for each Teleprinter are taken to a small Intermediate Distribution Frame, where a jumper field allows any necessary re-arrangement of lines in relation to bays to be made. The five wires then pass to the instrument table *via* double jack strips on the relay test bay. At this point, by means of five pin plugs and cords, a working line can be transferred to any Teleprinter set in the instrument room as desired. Facilities for the concentration of working sets are thus available, simplifying supervision, and enabling sections of the room to

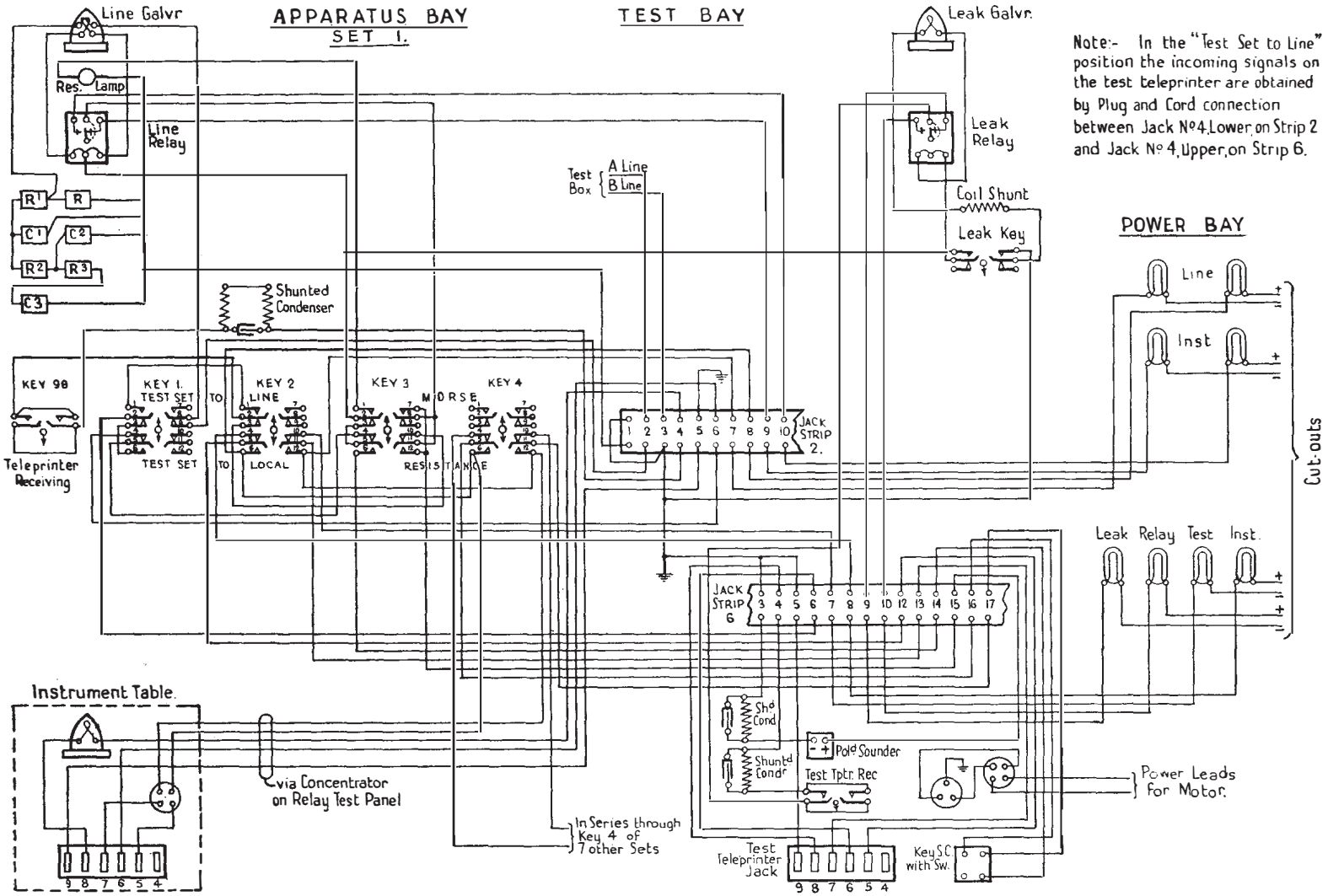


FIG. 5.—SCHEMATIC DIAGRAM OF A TELEPRINTER CIRCUIT.

be closed as the number of working circuits is reduced. The circuit connections are those in use for the standard Teleprinter duplex installation. The schematic diagram, Fig. **5**, allows the circuits made in the various positions of the key switches to be traced. The instrument table apparatus is confined to a Teleprinter with socket and battery cut-off switch for the motor circuit; a galvanometer in the receiving circuit, and a battery cut-off switch in the line battery circuit.

A section of bays to accommodate Morse circuits is provided. The general arrangement follows that of the Teleprinter Sections, the principle difference being that a less complicated system of key switches is required. At the instrument table a Morse key, sounder and tumbler switch are installed. The circuit may be worked either duplex or simplex, according to the position of a key on the relative apparatus bay.

Relay Testing.—The Relay Test Bay, Fig. **6**, closely follows a design produced by the P.O. Research Section. Its function is to secure an exact and uniform adjustment of the P.O. standard relays by means of measurements taken with sensitive instruments instead of depending upon visual examination of the operating parts. A standard relay is supplied with the bay, also a baseboard to accommodate the relay under test. By manipulating key switches the following tests may be made:—

(1) Calibration test of the standard relay to ensure that its behaviour is correct and that the adjustment is good.

(2) Sensitivity test. A current of one milliampere is passed through the relay coils and then reversed; the milliammeter should follow the change of direction.

(3) Neutrality test. Alternating currents at a speed of 50 p.p.s. are passed from the standard relay through the coils of relay under test, causing the latter to send reversals through the neutrality indicator. Any mechanical bias on the relay will be shown by the indicator and may be rectified by means of the biassing screw of the relay.

(4) Armature travel test. Alternating currents as in (3) are passed through the relay under test. The same pole of the battery is joined to both local contacts of the relay under test, whilst the tongue is joined to the coils of the neutrality indicator. If the relay tongue were at rest a full scale deflection would be produced on the indicator, irrespective of the contact engaged. When the relay tongue is vibrating, the full scale deflection is reduced by an amount dependent upon the width of the gap through which the tongue

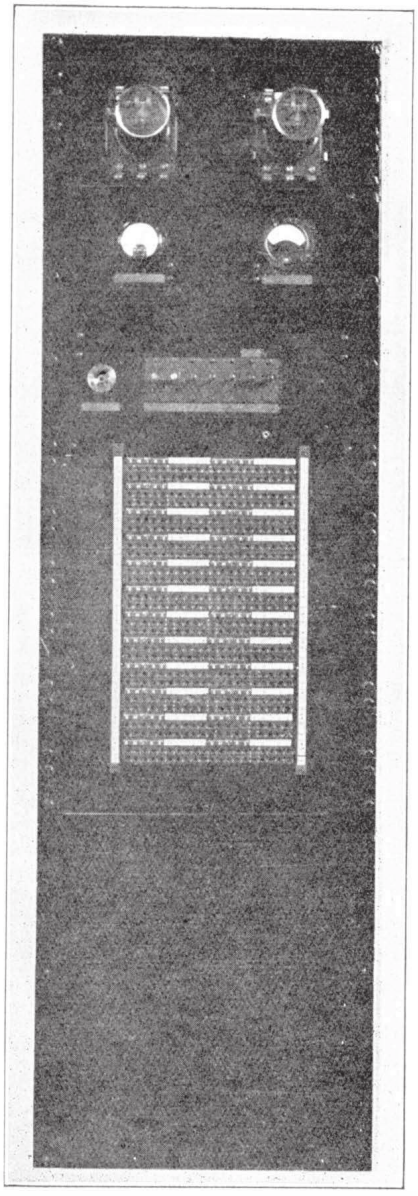


FIG. 6.—RELAY TEST BAY.

has to travel. If, therefore, a full scale deflection is regarded as 100% contact time, the actual reading observed on the indicator may be taken as the percentage contact time. It is thus possible to grade individual relays according to the efficiency required for any given circuit.

(5) Measurement of speed of telegraph signals.

tion on the speed indicator is approximately proportional to the speed at which the relay tongue is vibrating and, by the use of suitable values of resistance and capacity, the speed indicator is calibrated to give a direct reading of words per minute on one scale and periods per second on another. This test is useful for checking the speed of vibration of a Standard " G " relay.

The lower portion of the relay test bay is occupied by 24 rows of jacks arranged in pairs,

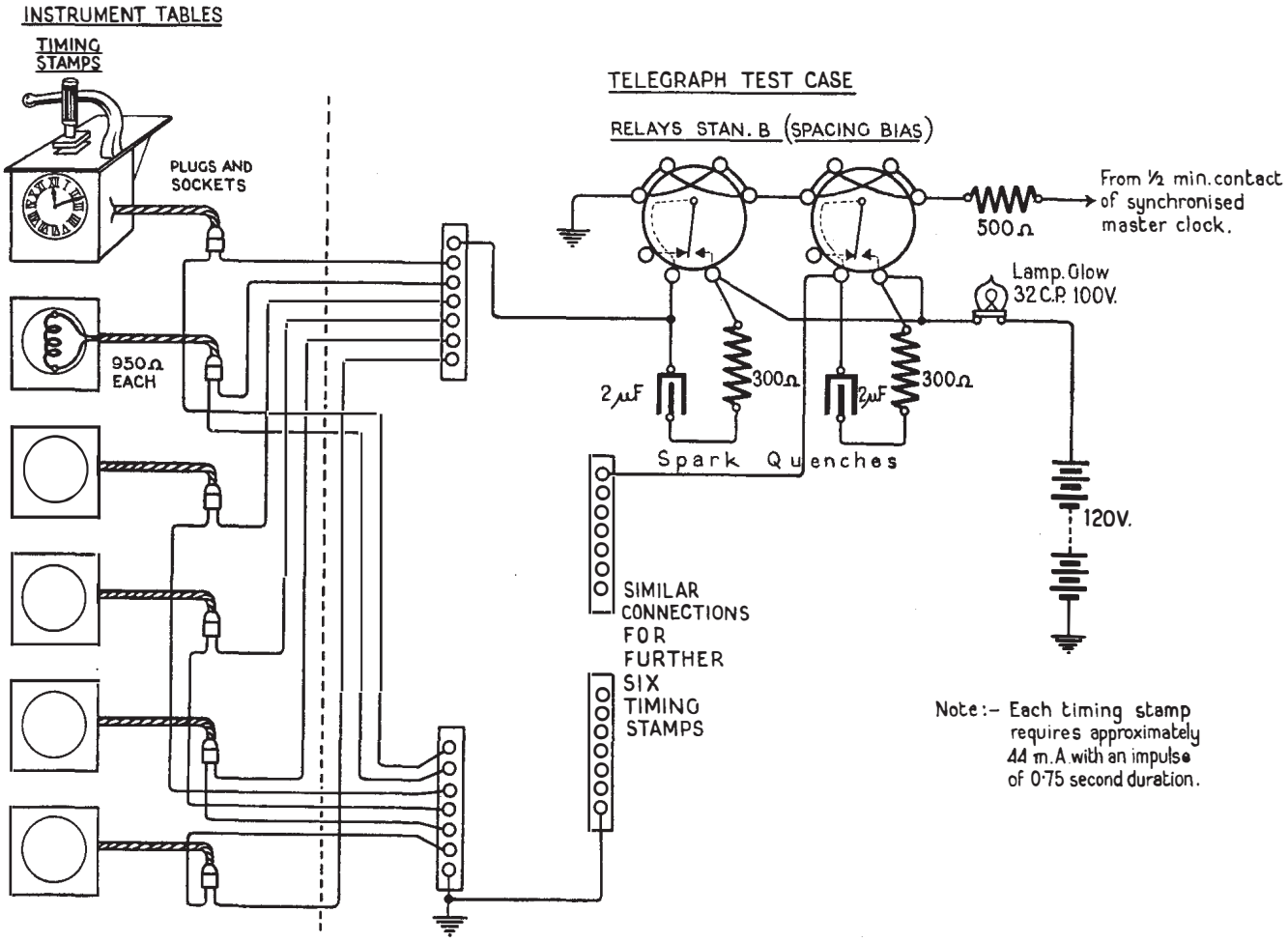


FIG. 7.—BLICK TIMING STAMPS. CIRCUIT ARRANGEMENTS.

The speed of reversals on a circuit may be measured by making a plug and cord connection to a jack on the bay; the reversals then pass through the coils of the standard relay. The tongue of this relay is joined to a condenser which is charged when the tongue makes contact on the marking side and discharged when it makes contact on the spacing side. The deflec-

five pairs being allotted to each Teleprinter set, providing for concentration as already mentioned.

Timing stamps.—Twelve Blick timing stamps have been installed on the receiving side of the busiest teleprinter circuits. The stamps are operated manually and give an impression upon the message form, (which is placed in position

with face downwards) of the hour, minute, a.m. or p.m., and the circuit designation. The stamps have been designed to operate with a current value of less than 50 mA, which is given at half minute intervals from a synchronised Master clock of the Post Office pattern. Fig. **7** shows the circuit details.

Conveyors.—The instrument tables are 1′ 9″ wide, with the exception of one wider table in use experimentally. They are placed in pairs with a space of 2″ between each table and a gangway of 5′ between each pair of tables. Five double tables are provided with conveyors which run between and below the level of the tables. Access to the conveyors is obtained by means of a " Vee "-shaped channel, $1\frac{7}{8}$″ wide at the top, narrowing to $\frac{1}{8}$″ at a depth of 5″. The sides of the channel are of No. 16 S.W.G. sheet steel. Fig. **8** shows a photograph of a double table and

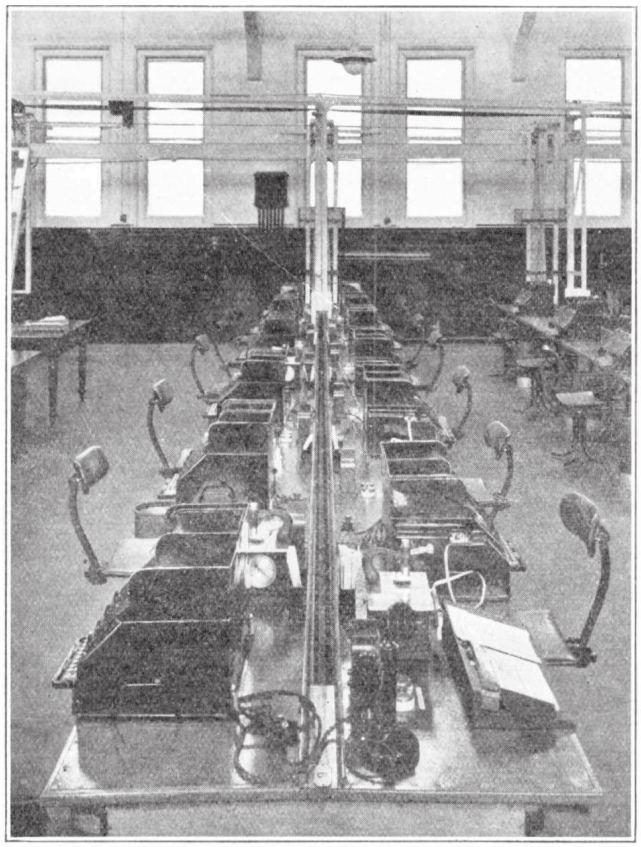


Fig. 8.—Instrument Table with Conveyor.

Fig. **9** a sectional view of the conveyor. At the base of the channel a continuously running

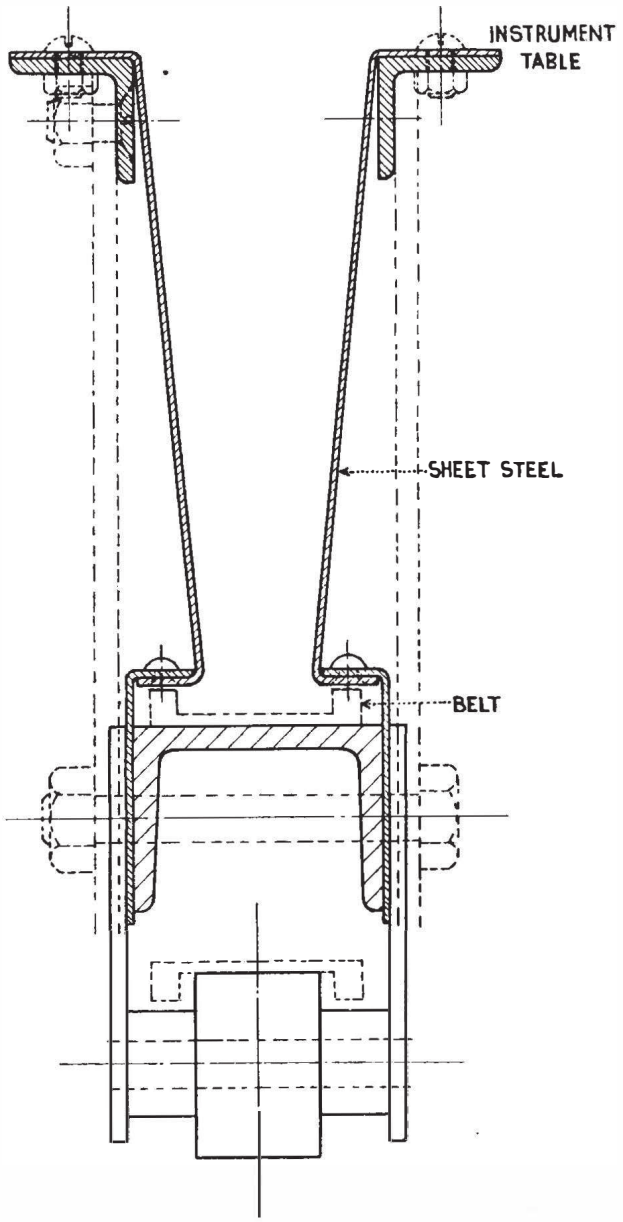


Fig. 9.—Conveyor in Section.

belt, $1\frac{7}{8}$″ wide, travels at a speed of 180 feet per minute. A separate motor is provided to drive each belt. The message forms are dropped into the channel and travel on edge to the end of the table where they are discharged into a riser belt, Fig. **10**.

The rollers of a riser belt are arranged in such a manner that the messages are taken from the table " Vee " conveyor in a vertical position, are then turned into a horizontal

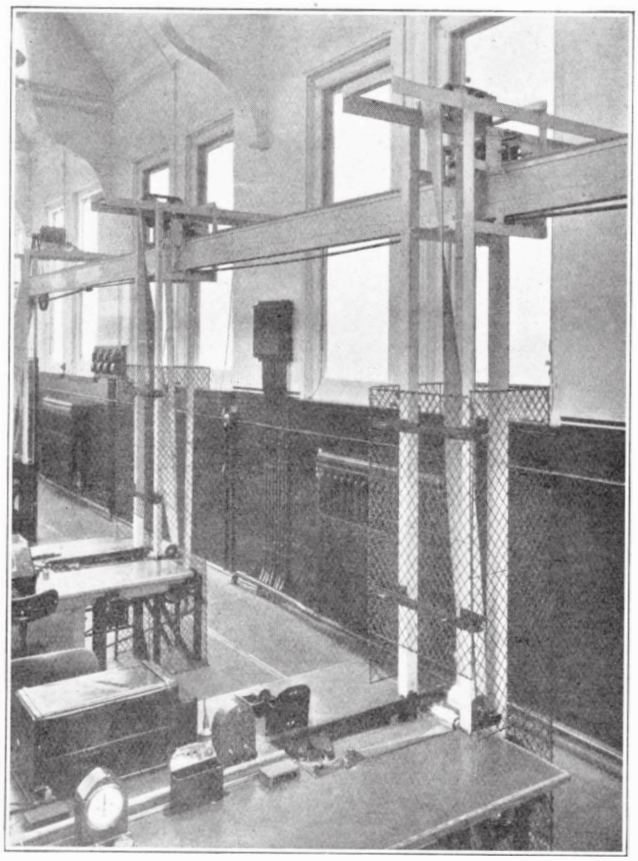


FIG. 10.—RISER BELT TO OVERHEAD CONVEYOR.

position, and delivered by rollers as shown in Fig. **11** into an overhead "Vee" conveyor. Two overhead "Vee" conveyors, each fed by

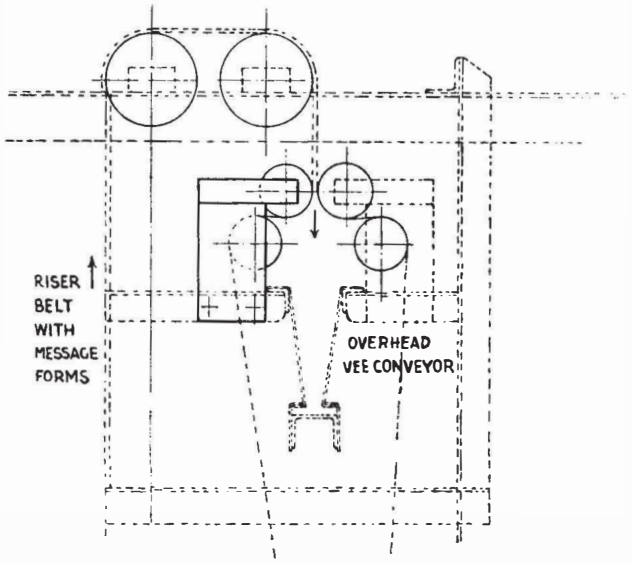


FIG. 11.—DETAILS OF DELIVERY TO OVERHEAD CONVEYOR.

three riser belts, run at right angles to the instrument tables at a height of 9′ from the floor level and converge at the circulation table, where the messages are delivered *via* a reinforced glass chute, with hinged front, on to a slow moving band, 9″ wide, travelling along the centre of the table.

In addition to the system for collecting received messages, messages for despatch are conveyed from the circulation table to two drop points, the Phonogram Room and the Concentrator. The two riser belts serving these points are fed by hand through chutes at the bottom of which the messages are gripped between two belts and are conveyed vertically to a height of 10′ and then horizontally to the points mentioned. The belts release the messages above a chain curtain chute down which they fall on to the table. Messages for dispatch on Teleprinter circuits are conveyed from the circulation table by hand as the circuits are grouped in close proximity. The introduction of the conveyors has reduced delay in circulation to a minimum.

The advantages arising from the re-arrangement, from an engineering point of view may be summed up as follows:—

(1) Economy of space. The same number of circuits have been accommodated in approximately two-thirds of the instrument room.

(2) Economy of apparatus, *e.g.*, only one Morse key and sounder is required for each group of eight Teleprinter circuits.

(3) Rapid and accurate localisation of faults on the instrument side by means of the interpolation of jacks in each instrument lead.

(4) Concentration of the testing of lines, instruments, and batteries at one point.

(5) The wiring at an Instrument table is reduced to a minimum.

(6) Any engineering work required can be carried out without impeding the Traffic staff.

(7) Facilities for observing the signals in both directions.

(8) Reduced risk of faults arising from wires making bad connection with screw terminals or being broken at the tables.

TELEGRAPH INTERNATIONAL 5-UNIT CODE.

A. C. BOOTH.

IN the issue Vol. 15, Part 3, of October, 1922, the position in regard to this subject was explained with a suggestion that endeavours should be made to obtain one 5-unit code instead of the three that were then in use. Subsequent to that article the Comité Consultatif International des Communications Télégraphiques, known as the C.C.I.T., was formed to deal with all subjects that had a bearing on international telegraphy. Among other matters, this subject of the 5-unit code was included for consideration and was dealt with at the meetings of 1926 and 1929 in Berlin. As was to be expected, there was considerable opposition to the slightest alteration in the Baudot code, but at the second meeting a few alterations were accepted. These modifications were not sufficient to admit of the use of one 5-unit code for different systems and the net result is that there are still two 5-unit codes, as shown in the accompanying diagram, Fig. 1. These two codes have not yet been finally accepted by all Administrations, but it is expected that there will be no opposition.

The endeavour to induce the users of the Baudot code to make sufficient alteration to admit of the use of the simplest form of alphabetical keyboard, whether perforator or direct sender, was with a view to retain the Baudot code if at all practicable. The difficulties of making the required changes are well recognised, but it is considered that the change would have been worth while. However, the endeavour failed, and, although the second code is based on the Baudot code, it will be seen that it is almost completely reversed, thus constituting an entirely new 5-unit code from the operator's point of view, both in regard to a perforated tape and from the action of the " marking " currents on the electromagnet or magnets.

This result is the best that it has been possible to obtain after nearly eight years of discussion, and it is rather a pity in some respects that the Baudot code is thus doomed to disappear entirely in the course of the next few years, as it must do with the rapid growth of the modern systems of

ALPHABET No. 1. For Multiplex Service.

No. of Signal.			1	2	3	4	5
1	A	1	o				
2	B	8				o	o
3	C	9	o			o	o
4	D	0	o	o	o	o	
5	E	2		o			
6	F	x)		o	o	o	
7	G	7		o		o	
8	H	+	o	o		o	
9	I	x)			o	o	
10	J	6	o				o
11	K	(	o			o	o
12	L	=	o	o		o	o
13	M	)		o		o	o
14	N	x)		o	o	o	o
15	O	5	o	o	o		
16	P	%	o	o	o	o	o
17	Q	/	o		o	o	o
18	R	−			o	o	o
19	S	.			o		o
20	T	x)	o		o		o
21	U	4	o		o		
22	V	'	o	o	o		o
23	W	?		o	o		o
24	X	,		o			o
25	Y	3			o		
26	Z	:	o	o			o
27	LTR SPACE	LTR SPACE					o
28	FIG SPACE	FIG SPACE				o	
29	⁂	⁂				o	o
30	REPOSE						
31	CARRIAGE RETURN		o	o			xx)
32	LINE CHANGE		o			o	xx)

NOTES:- o indicates a Negative impulse and perforations when tape transmission is used.

x) is Reserved for Interior service.

xx) is Reserved for column printers.

For Anglo-Continental Teleprinter service the Start signal is a negative impulse and the Stop signal is a positive impulse.

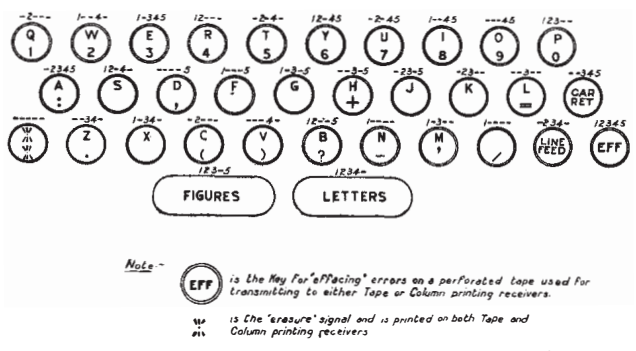
On Central Battery circuits the signalling is done by breaking the positive spacing current. Hence the code representation of the small circle will mean "no current" or "zero current" and not a negative

⁂ Indicates an erasure signal.

ALPHABET No. 2. For Teleprinter Service.

No. of Signal			1	2	3	4	5
1	A	:		o	o	o	o
2	B	?	o	o			o
3	C	(		o			o
4	D	,					o
5	E	3	o			o	o
6	F	/	o				o
7	G	x)	o		o		o
8	H	+			o		o
9	I	8	o			o	o
10	J	Bell		o	o		o
11	K	x)		o	o		
12	L	=			o		
13	M	'	o		o		
14	N	−	o				
15	O	9				o	o
16	P	0	o	o	o		
17	Q	1		o			
18	R	4	o	o			
19	S	x)	o	o		o	
20	T	5		o		o	
21	U	7		o		o	o
22	V	)				o	
23	W	2	o			o	
24	X	x)	o		o	o	
25	Y	6	o	o		o	o
26	Z	.			o	o	
27	LTR SPACE	LTR SPACE	o	o	o	o	
28	FIG SPACE	FIG SPACE	o	o	o		o
29	⁂	⁂					
30	EFFACEMENT		o	o	o	o	o
31	CARRIAGE RETURN				o	o	o xx)
32	LINE CHANGE			o	o	o	xx)

FIG. 1.—TELEGRAPH INTERNATIONAL 5-UNIT ALPHABETS (1929).



Note - EFF is the Key for 'effacing' errors on a perforated tape used for transmitting to either Tape or Column printing receivers.

⁂ is the 'erasure' signal and is printed on both Tape and Column printing receivers

FIG. 2.—TELEPRINTER KEYBOARD FOR CONTINENTAL CIRCUITS. INTERNATIONAL ALPHABET No. 2.

telegraphy. Admirers of the Baudot system would certainly have preferred to have seen its code brought up to date, rather than to see it displaced by an entirely new one.

The keyboard lay-out for the British apparatus that will use the second code is arranged as shown in Fig. 2. It explains the use of the two erasure keys, one of which is marked with the well-known erasure signal and the other with EFF. The three keys, Carriage return, Line feed and Effacement need not be used until column printers are fitted at the receiving end.

APPLICATIONS OF THE THERMOSTAT TO TELEGRAPH CIRCUITS.

N. F. Frome, D.F.C., B.Sc., A.M.I.E.E., Agra, India.

THE use of the thermostat as a means of time control in automatic telephone circuits is well known. The following applications of the device for providing calling and alarm signals in various types of telegraph circuit may be of interest :—

(1) *Closed Circuit Morse Lines.* — A concentrator switchboard for use on closed circuit lines is illustrated in Fig. 2. The switchboard shown is arranged for concentrating ten lines, and is fitted with strips of ten line jacks, line lamps, set jacks and " clear " lamps. Fig. 1 shows the line circuit. A fast low-resistance relay F, which responds to the line signals, is interposed between the line and the battery tap. In the local circuit of F is a high resistance slow relay S, permanently operated, and controlling the thermostat T and a locking relay R. When signals are being sent between any two stations on the line, F responds, but S only gives

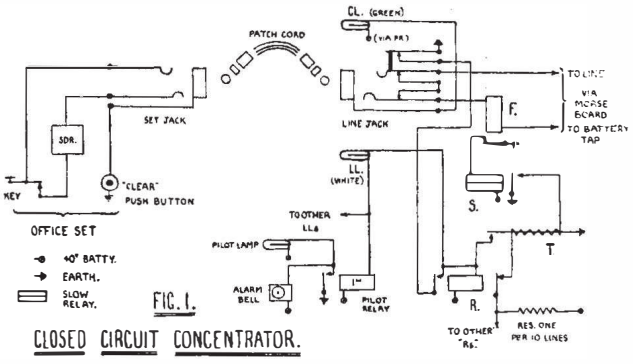


FIG. 1.

CLOSED CIRCUIT CONCENTRATOR.

occasional flicks. If, however, F is given a prolonged release, S is de-energised, the thermostat heats and operates, closing the circuit of R. R is arranged to open the thermostat circuit, light the line lamp, pilot lamp, and operate the alarm bell, locking to an earth on the line jack. The calling signal remains locked therefore until the

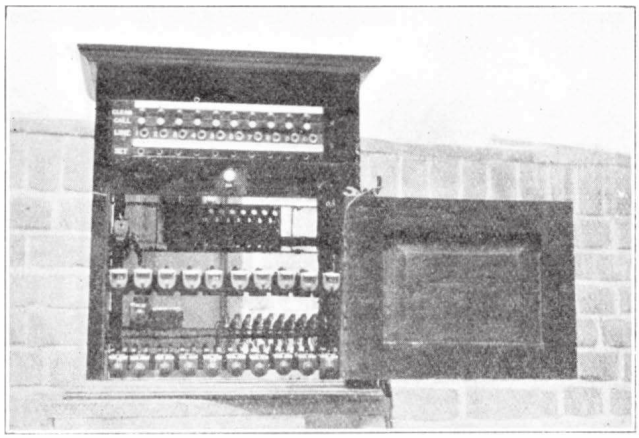


Fig. 2.—10-Line closed Circuit Concentrator.

call is answered, *i.e.*, until a patch-cord is plugged into the line jack. The other end of the cord is plugged into the office set jack on which the section traffic controller wishes to work the calling station.

In practice, out-stations on the closed circuit lines are instructed to call the central station by holding the key down for thirty seconds. The thermostat is arranged to operate after twenty seconds, allowing a safe margin.

When the telegraphist has finished working with the out-station, he gives the " Clear " signal by pressing a push-button fitted on the set. The lamp CL lights, *via* the sleeve conductor of the patch cord, and operates the pilot relay and alarm bell.

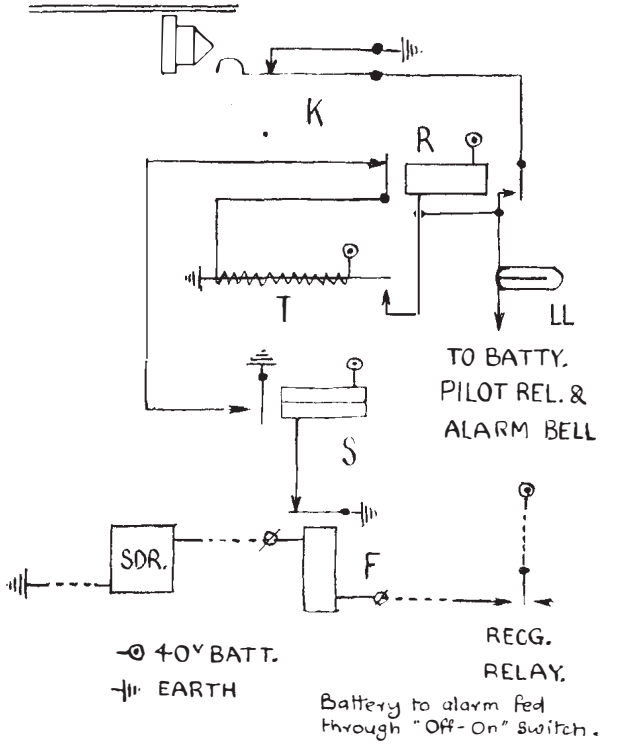
Should the telegraphist forget to clear (or the patch cord is not removed to clear the connection)

and an out-station endeavours to call, as can be seen from the line circuit diagram, the thermostat will operate and give an intermittent flashing and ringing signal to call attention.

The device can of course be adapted to act as a calling alarm on closed circuit lines apart from the use for concentrator working cited above.

(2) *Duplex Morse Repeaters.*—Fig. **3** shows the calling device as arranged for calling Morse duplex repeater stations into circuit. The alarm circuit used is similar to that of Fig. **1**. F is introduced into the receiving circuit of the duplex repeater and the operation of F, S, T and R is similar to that already described. Two alarm units are used on the repeater set so that either

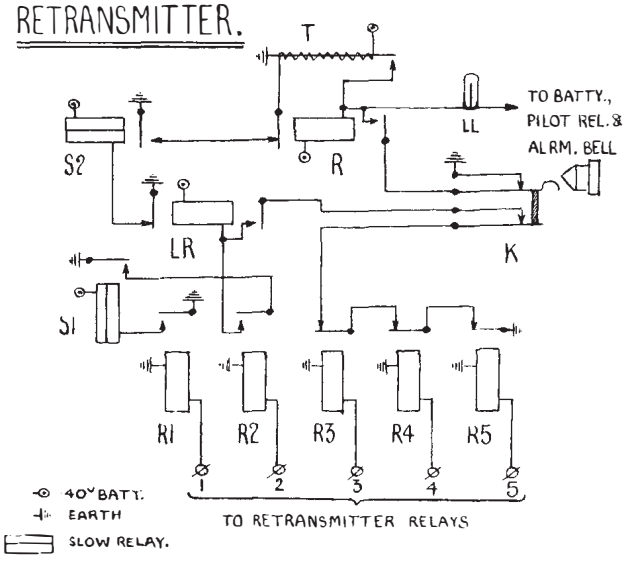
ALARM FOR DUPLEX MORSE REPEATER. FIG.3.



terminal station operator by holding his key down for thirty seconds can give the alarm signal on the repeater, and call the attention of the repeater supervisor. The release of the R relay in this circuit results from the operation of the push-button type key K.

(3) *Baudot Re-Transmitting Repeater.* — A modified form of the same alarm circuit for use on Baudot re-transmitting repeaters is shown in Fig. **4**. In this case five low resistance relays,

ALARM FOR BAUDOT RETRANSMITTER. FIG.4.



R1—R5, are arranged to work in parallel with the re-transmitting relays and respond to the same signals. A slow relay S1 is energised by the operation of R1, and earths the lever of R2. When R2 operates, this earth energises a locking relay LR. If R3, R4, or R5 operates after R2, LR is immediately unlocked and owing to the rapidity of the action of the relays the slow relay S2 is not released. If, however, no third, fourth or fifth impulse follows the first and second for some time, S2 releases and the thermostat operates after twenty seconds, as in the circuits previously described. In other words, for all combinations of the five units except for " Firsts and Seconds " (" É " in the letter column, or " & " in the figure column) the alarm will not respond, but in response to a succession of " És " or " &s," the thermostat operates, and the alarm lamp and bell call the attention of the Baudot supervisor. The alarm is released by the operation of the push-button key K which unlocks both locked relays. This device has the advantage of giving a positive calling signal and also eliminates the necessity of continuously running receivers on re-transmitting sets.

VOICE FREQUENCY KEY-SENDING FROM "A" POSITIONS.

I. H. Jenkins, M.I.E.E.

THE installation of an automatic exchange, whether in a single exchange area or in a large multiple exchange area such as London, necessitates provision for handling traffic originating in contiguous or distant manual exchanges, and flowing into the automatic exchange. This has constituted a problem of some dimensions ever since the introduction of automatic switching equipment. The comparatively simple case of the single exchange area with very small groups of incoming lines to the automatic exchange involved designing "tricky" circuits (see *Post Office Electrical Engineers' Journal* of October, 1925) both for accommodation of the dial at the manual end and for linking up the line to the selectors at the automatic end. The large area involving large manual exchanges, however, constitutes a bigger problem with wider economic possibilities. In these areas the use of dials on the manual exchange A positions becomes too costly because of the high call value of calls to automatic exchanges. The only permissible scheme is the use of key-sending equipment with digit keys, operated either on the A position or on a B position interposed between the manual exchange and the automatic exchange. The placing of the digit keys on the A positions is recognised as being the best arrangement and much work has been done during the past few years in endeavouring to evolve a satisfactory solution along these lines. A scheme which does accomplish this, satisfactorily employing voice frequency alternating currents for transmitting code impulses to the sender storage relays, has recently been evolved and it is the purpose of this article to describe it in outline.

In order to put it in its proper setting it is desirable to review briefly the schemes which have been used and tried out, and which have led to the evolution of this method.

Order wire key sending positions are well known, having been installed in all the automatic exchanges yet opened in London. In this method the equipment and operation at the manual end is precisely similar to that used for manual to manual order wire working. The A operator orders up the connection on an order wire and plugs into a junction assigned by the B operator at the automatic exchange end. The B position accommodates some 30 to 35 incoming junctions appearing in lamps and keys. The B operator allots the junction for each call, presses an assignment key and keys up the number required on a strip of digit keys, the clearing being in the hands of the A operator.

An early attempt to place the digit key on the A position is represented by the Museum Exchange equipment, which was described in the *Post Office Electrical Engineers' Journal*, April, 1926, by Mr. J. Hedley. This equipment, while being satisfactory from a traffic point of view, has distinct limitations in that the outgoing lines cannot be multipled and a very

large quantity of automatic apparatus is required in the manual exchange.

The next development to be considered is the straight-forward junction scheme which, as worked out by Post Office engineers, has been installed at Manchester and Birmingham. In this scheme, the keying is not placed in the hands of the A operator, but the unsatisfactory order wire working is replaced by a new method. The A operator selects an idle junction and plugs into it. This action causes an available B operator from a group of positions to be automatically associated with the junction at the automatic exchange end. The A operator is advised by a " zip-zip " signal that the B operator is ready to take the demand, the B operator takes the call and keys up the number required. She has no assignment keys to operate and is automatically released from a call and lined up for the next call.

Straight forward junction working is referred to in the July, 1930, issue of *The Post Office Electrical Engineers' Journal* by Mr. L. F. Morice in an article dealing with " Manchester Automatic Telephone System." Fig. 8 is reproduced from that article and shows clearly the circuit lay-out. It was realised when this scheme was worked out for Manchester that there were possibilities, if satisfactory circuits could be devised, of placing the digit key on the A position and so eliminating the B operator. An attempt was later made to accomplish this in the design of mechanical order wires. In this system a 4-wire order wire is used and arrangements are made to associate it automatically with the digit key at the manual exchange and with the senders in the automatic exchange. Two forms of this scheme have been worked out. In the first one, now some years old, designed by Messrs. Siemens, and described by Mr. D. A. Christian in *The P.O.E.E. Journal* of July, 1928, a display panel was fitted on the A operator's position, the A operator pressing the order wire button and the automatic apparatus causing the display panel to indicate the junction assigned. She then plugged into the junction and keyed up the number on the digit key strip. A variation of this scheme still using an order wire was also worked out by Messrs. Siemens, somewhat on the lines of straight-forward junction working, the A operator plugging into an idle junction and on the receipt of a " zip-zip " signal keying up the number. These schemes, whilst being very satisfactory from a traffic point of view, still had the disadvantage of being complicated and requiring a large amount of apparatus at the manual end.

At this juncture, whilst considering mechanical order wire circuits, it was suggested that a separate order wire for passing impulses might be avoided by using four frequencies of AC current within the voice range, which could be coded to give all the signals required for 10 digits, and passed over the talking circuit. A system, the basic principles of which could be adapted to this purpose, already existed in the Standard Telephones & Cables scheme designed by them for key-sending over trunk lines, and shortly to be placed in service on the Leeds-London trunks. The scheme, however, as now

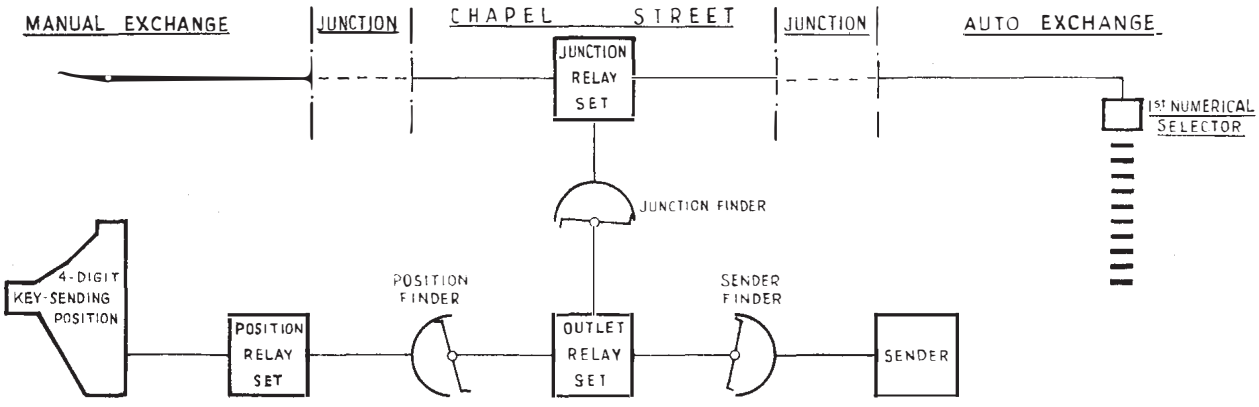


FIG. 8 FROM " MANCHESTER AUTO TELEPHONE SYSTEM " (*P.O.E.E. Journal*, July, 1930).

applied to short distance junction working, differs from that designed for long trunk operation in that a direct current is used over the junction to control the signals and hold the selectors. The voice frequency signals are used only to set up the storage relays in the sender at the automatic exchange. Any device for preventing interference from actual speaking currents on the line is avoided by arranging the circuit so that, after the automatic apparatus has lined up the digit key at the manual exchange with the receiving apparatus at the automatic exchange, a signal is sent over the line by depression of the cancel key to ensure that the storage relays in the sender are set at zero before actual digiting takes place. The advantage of this scheme is that the equipment at the manual exchange becomes very simple. A source of supply for voice frequency currents and its connection to the commons of the digit keys, together with some modifications to the A cord circuits, which are not of a formidable nature, is all that is required. Further, the Post Office standard straightforward junction circuits, as used in Manchester and Birmingham, can be readily adapted for voice frequency key sending. Reference to the Figure will show that it is a simple matter to replace the position relay set and operator's position itself by a voice frequency receiving set, which will perform the functions of the B operator by accepting the voice frequency coded impulses and translating them to the storage relays in the sender.

A trial equipment of this scheme has been working for some months in London and has proved very promising. Further development will be necessary to perfect the system, but sufficient has been done to make it quite clear that it has important possibilities and will be extensively employed in local and toll area networks. It will also in all probability be extended to longer trunk lines.

In a future article further details will be given.

PROBLEMS IN AUTOMATIC TRUNKING—LAST CONTACT TRAFFIC.

N. A. Hawkins, A.M.I.E.E.

Outline of Contents.

(*a*) Introduction.
(*b*) Theoretical considerations,
  (1) The case of full availability.
  (2) The case of grading.
(*c*) Some practical applications with examples.

(*a*) *Introduction.*

THE trunking aspect of automatic telephony has been described in detail in a number of articles written by Mr. G. F. O'dell, of the Engineer-in-Chief's Office, and others, so that the majority of the readers of this journal are familiar, to a greater or less degree, with the principles of this branch of telephony. The purpose of this article is not therefore to repeat, except in a few details, what has already been written but rather to introduce another phase which is not generally known.

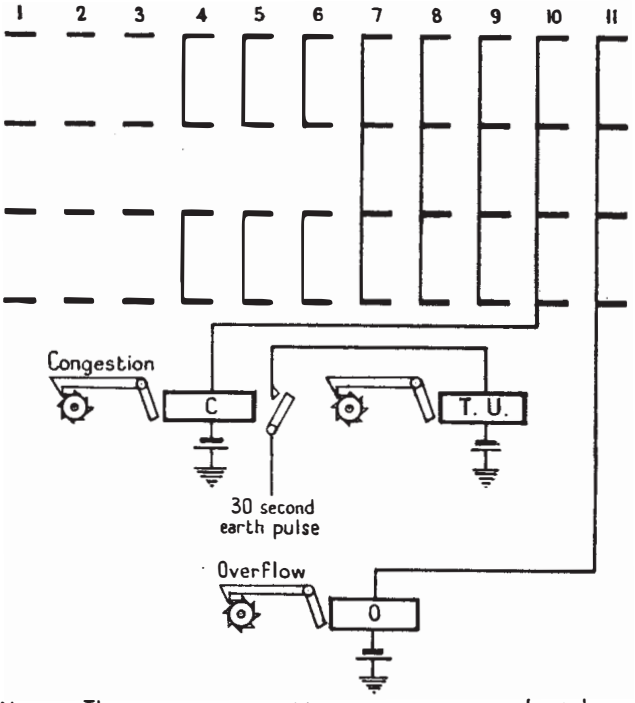
Before presenting the mathematical treatment on which this article is based, it is necessary to describe briefly a portion of the traffic metering facilities which have now been standardised in automatic exchanges. There are two types of traffic meters in practical use (*a*) overflow meters and (*b*) congestion meters. The latter consists of a set of two meters, one recording calls and the other being operated in a local circuit of the former by a 30 seconds earth pulse.

These meters fulfil the following functions:—

1. Overflow meters. Being associated with the 11th or 21st contact in the private bank of all switches having access to a full availability or graded group of outlets, dependent upon the size of the bank, record all calls, which, by virtue of the traffic passing through the particular route, are unable to seize an idle outlet in the next rank.
2. Congestion meters. The congestion call meter records the total number of times the last choice in a full availability or

graded group of outlets is brought into use. The meter associated with this, called the traffic unit meter registers by means of the 30 second earth pulse the time the last choice is in use.

Fig. 1 shows the method of connecting traffic meters to a typical grading.



Note:- The meter connections are associated with the private bank contacts.

FIG. 1.

Considering the traffic unit meter, and bearing in mind that one traffic unit is equivalent to one call hour or 120 call-half minutes per hour, it is apparent that by dividing readings obtained on the meter during one hour by 120 we obtain directly what traffic is being carried by the last choice of a particular group of outlets.

It is desirable to mention something about "grade of service." Grade of service is the proportion of calls which are allowed to fail during the busy hour, owing to the limitation, for economic reasons, of the amount of switching plant, the Post Office standard for which can be stated as follows :—

"When the traffic is normal, the grade of service per switching stage shall not be worse than 1 in 500. If the traffic increase temporarily by 10 per cent., the grade of service per switching stage shall not fall below 1 in 100."

The value of the grade of service being definite, the switch quantities required for given values of traffic are determinate from theories adopted as standard in Post Office design and generally the arrangement of the switches or rather the "trunking" in the exchange follow standard lines. The traffic tables used for automatic exchange design are given in Technical Instruction XXV., Part 12A.

(*b*) *Theoretical Considerations.*

The mathematical treatment which follows is subdivided into the cases of (1) full availability and (2) grading. It is thought that such elementary terms as these are so well known that it is not necessary to discuss their meaning.

(1) *Full availability.*

The theory adopted by the Post Office for design purposes is that of A. K. Erlang, of the Copenhagen Telephone Co., which states that if A is the total traffic offered to a group of x switches, the proportion of lost calls or grade of service P_x is given by the following expression :—

$$P_x = \frac{\frac{A^x}{x!}}{1 + A + \frac{A^2}{2!} + \ldots\ldots + \frac{A^x}{x!}} \quad \ldots\ldots(1)$$

Direct reasoning from this indicates that the proportion of calls P_{x-1} passed on from the $(x-1)$th switch will be

$$P_{x-1} = \frac{\frac{A^{x-1}}{(x-1)!}}{1 + A + \frac{A^2}{2!} + \ldots\ldots + \frac{A^{x-1}}{(x-1)!}} \quad \ldots(2)$$

It will be evident from first principles that traffic carried by last switch or contact = traffic offered to last contact − lost traffic or last contact traffic $= AP_{x-1} - AP_x$

$$= A(P_{x-1} - P_x) \quad \ldots\ldots(3)$$

Transposing expressions (1) and (2) we have

$$P_x\left[1 + A + \frac{A^2}{2!} + \ldots\ldots \frac{A^{x-1}}{(x-1)!}\right] = \frac{A^x}{x!}(1 - P_x) \quad \ldots\ldots(4)$$

$$P_{x-1}\left[1+A+\frac{A^2}{2!}+\ldots\ldots\frac{A^{x-1}}{(x-1)!}\right]=\frac{A^{x-1}}{(x-1)!} \quad \ldots\ldots\ldots(5)$$

Dividing (5) by (4) the following results

$$\frac{P_{x-1}}{P_x}=\frac{\frac{A^{x-1}}{(x-1)!}}{\frac{A^x}{x!}(1-P_x)}$$

$$\text{or } P_{x-1}=\frac{xP_x}{A(1-P_x)} \quad \ldots\ldots\ldots(6)$$

Substituting the value of P_{x-1} from (6) in expression (3) it is seen that

$$\text{last contact traffic}=A\left[\frac{xP_x}{A(1-P_x)}-P_x\right]$$

$$=P_x\left[\frac{x}{(1-P_x)}-A\right] \quad \ldots\ldots\ldots(7)$$

$$=P_x(x-A) \text{ approximately}$$

since for a good grade of service P_x is small compared with unity.

The theory of W. H. Grinsted, which is an approximation to that of Erlang, is very nearly true for good grades of service and is expressed as

$$P_x=\frac{\frac{A^x}{x!}}{e^A} \quad \ldots\ldots\ldots(8)$$

where P_x, A and x have the same significance as before, e being the base of Naperian logarithms.

Similarly it is seen that the proportion of calls P_{x-1} passed on from the $(x-1)$th contact is

$$P_{x-1}=\frac{\frac{A^{x-1}}{(x-1)!}}{e^A} \quad \ldots\ldots\ldots(9)$$

From (3) results

$$\text{last contact traffic}=A(P_{x-1}-P_x)$$

and therefore in this case

$$\text{last contact traffic}=A\left[\frac{\frac{A^{x-1}}{(x-1)!}}{e^A}-\frac{\frac{A^x}{x!}}{e^A}\right]$$

$$=\frac{\frac{A^x}{x!}}{e^A}[x-A]$$

$$=P_x(x-A) \quad \ldots\ldots\ldots(10)$$

a result which is in agreement with the approximation to that deduced from Erlang's theory for a good grade of service.

Analysing expression (7) it is seen that since last contact traffic = traffic offered to last contact − lost traffic

$$\text{Traffic offered to last contact}=\frac{P_x x}{1-P_x} \quad \ldots\ldots(11)$$

From this it is apparent that providing the grade of service is stated we can always determine the traffic offered to the particular outlet without knowing directly the value of the total traffic offered to the group. The application of this will be considered in a later portion of this article.

(2) *Grading.*

The case of grading does not admit of easy mathematical treatment. Though the problem has been attacked by several investigators, their results are too complicated to be of practical service.

In determining the traffic carried by each contact in a grading, therefore, use has been made of a theory published by Dr. Lubberger in Germany in 1924, and developed independently in the Post Office Engineering Department. This assumes that the traffic carried by each contact is the same as it would be if the same amount of traffic were offered to the corresponding contact in a full availability group. It therefore follows that if the traffic giving the same loss in a full availability group is determined for any given traffic offered to the grading, the traffic carried by the last common contact of the grading will be the same as the traffic carried by the last contact of the full availability group.

In the following paragraphs concerning grading use is made of the term "equivalent full availability traffic." This term is applied to an amount of traffic which, if offered to a full availability group with the same availability as a given grading, will result in the same amount of lost traffic as is actually experienced with the grading for a given total traffic offered. Thus in a particular case it was found that with a 10-contact grading of 30 switches the lost traffic was .082 traffic unit when 14.8 traffic units were offered. With a full availability group of ten circuits, 4.91 traffic units would need to be offered

to give this loss. Then 4.91 traffic units is called the " equivalent full availability traffic " to 14.8 traffic units actual traffic for this particular grading.

The condition which must be fulfilled is that the lost traffic for the graded group must be equal to the lost traffic for the equivalent full availability traffic. Hence, if A′ is the actual traffic and A is the equivalent full availability traffic, and B′ and B the respective grades of service,

then $BA = B'A'$ .....(12)

Now for a full availability group

$$\text{last contact traffic} = P_x\left[\frac{x}{(1-P_x)} - A\right]$$

(See expression (7).

$$= P_x A\left[\frac{x}{(A-P_xA)} - 1\right]$$

$$= \text{loss}\left[\frac{x}{(A-\text{loss})} - 1\right] \quad ..(13)$$

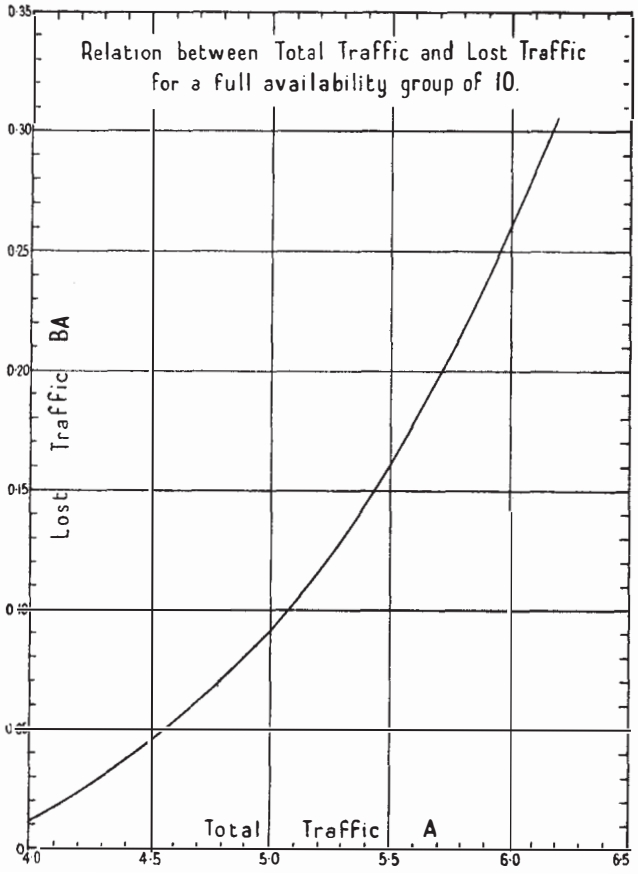


FIG. 2.

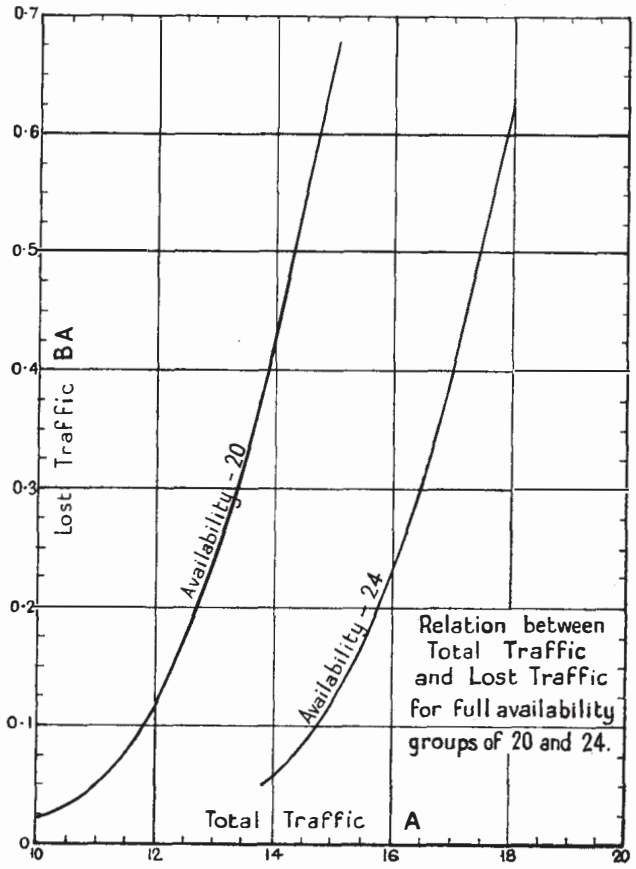


FIG. 3.

which is a convenient alternative to expression (7) and by substituting the value of A gives the last contact traffic for the equivalent full availability traffic.

On the theory mentioned above this will also be the last contact traffic for the grading when traffic A′ is offered to it. In this case, however, the lost traffic cannot be neglected in comparison with the equivalent full availability traffic A, since their ratio is above 1 in 500 and for large graded groups may be above 1 in 100.

The only unknown quantity in expression (13) is A, that is, the equivalent full availability traffic. Curves have been prepared and are shown in Figs. **2** and **3**, giving the relation between lost traffic and traffic offered to full availability groups of 10, 20 and 24. These are the only availabilities at present in use and therefore we can determine from these curves what will be the equivalent full availability traffic to give the same value of lost traffic as would be obtained from a graded group. Then by sub-

stituting the relative values in expression (13) the last contact traffic is obtained. There is an approximation to expression (13) which is rather useful for checking purposes, but has only a limited application as indicated later.

Repeating expression (13)

$$\text{last contact traffic} = \text{loss}\left[\frac{x}{(A-\text{loss})} - 1\right]$$

It is found by substituting N, the number of switches in the graded group for x the availability and A′ the traffic offered to the former for A, the equivalent full availability traffic, the value of last contact traffic obtained is very nearly equal to the correct value. This of course will only be nearly true when $\frac{x}{A}$ is approximately equal to $\frac{N}{A'}$.

It is therefore apparent that the approximation, namely,

$$\text{last contact traffic} = \text{loss}\left[\frac{N}{(A'-\text{loss})} - 1\right] \quad \ldots(14)$$

must be nearly true under certain conditions. These conditions are dependent upon (*a*) the availability; (*b*) the grade of service and (*c*) the number of switches in the graded group.

These are summarised as follows:—

1. *Availability 24.*

For a grade of service 1 in 200 the upper limit or highest value for which the approximation (14) can be used is 70 switches. For a grade of service of 1 in 500 the upper limit is 150 switches.

2. *Availability 20.*

For a grade of service of 1 in 200 the upper limit is 80 switches.

For a grade of service of 1 in 500 the upper limit is 100 switches.

3. *Availability 10.*

For a grade of service of 1 in 200 the upper limit is 50 switches.

For a grade of service of 1 in 500 the upper limit is 50 switches.

As an example of the error involved:—

When N = 150 A′ = 96.67 for B = $\frac{1}{500}$ x = 24

Then lost traffic = $\frac{96.67}{500}$ = 0.1933

The approximation gives

$$\text{last contact traffic} = \text{loss}\left[\frac{N}{(A'-\text{loss})} - 1\right]$$

$$= .1933\left[\frac{150}{96.67-.1933} - .1933\right]$$

$$= .1072 \text{ traffic unit.}$$

It is found from the relative curve that for a loss of 0.1933 traffic unit A = 15.67.

The correct value is therefore

$$\text{last contact traffic} = \text{loss}\left[\frac{x}{(A-\text{loss})}\right] - 1$$

$$= .1933\left[\frac{24}{15.67-.1933}\right] - 1$$

$$= 0.1064 \text{ traffic unit.}$$

The error in this case is only 0.8 per cent.

(*c*) *Practical Applications.*

It is proposed to arrange the subject matter under this heading in the order (1) existing uses and (2) suggested uses.

1. *Existing uses* (A). The foremost application of the principles given in the earlier portions of this article was, in reality the cause of a detailed investigation of the subject. The use of the congestion meter set to determine the last contact traffic has been mentioned previously. The present method of interpreting the meter readings so obtained is to compare them with values determined theoretically, which should not be exceeded. These values are such that the worst grade of service permissible, viz., 1 lost call in 200 is being given. Form T.E. 440 is used for the purpose of recording the differences between meter readings for each hour of the period 10 a.m.—12 noon on a representative day in the week agreed with the Traffic Department. The top of the form is divided in order to give the following headings of the columns:—

(*a*) Level or Group; (*b*) Number of trunks; (*c*) Average duration in minutes; (*d*) Critical connections and (*e*) Critical T.U. meter reading.

The first three terms are self-explanatory, (*d*) is the permissible number of calls taken by the last choice, at the given average duration and

(e) is the total duration in half-minutes of the engagement of the last choice when the grade of service has fallen to the lowest permissible figure. These figures apply to the busy hour.

Obviously 2 (c) × (d) = (e).

We have seen that the last contact traffic at any reasonably good grade of service can be determined in the case of full availability from

$$\text{last contact traffic} = B\,(x - A)$$

and for graded groups from

$$\text{last contact traffic} = \text{loss}\left[\frac{x}{(A - \text{loss})} - 1\right]$$

In the latter case, an even distribution of traffic is assumed, but, should this not obtain, the unevenness will be indicated by the meters when a sufficient volume of traffic is passing.

In an earlier paragraph it has been stated that one traffic unit is equivalent to 120 call-half minutes. Hence by multiplying the last contact traffic determined for the grade of service of 1 in 200, by 120 we get the critical traffic unit meter reading which it will be seen is independent of the average holding time of a call. The critical connections are therefore

$$\frac{\text{critical T.U. meter reading}}{2 \times \text{average holding time}}$$

TABLE 1.

No. of switches.	Traffic Unit Meter Reading.	Congestion Meter Reading.
1	0.60	0.12
2	1.13	0.22
3	1.60	0.32
4	1.98	0.40
5	2.32	0.46
6	2.64	0.53
7	2.90	0.58
8	3.16	0.63
9	3.40	0.68
10	3.62	0.72
11	3.83	0.77
12	4.03	0.80
13	4.22	0.84
14	4.42	0.88
15	4.57	0.91
16	4.74	0.95
17	4.90	0.98
18	5.05	1.01
19	5.20	1.04
20	5.34	1.07
21	5.48	1.10
22	5.62	1.12
23	5.75	1.15
24	5.87	1.17

Note :—Average duration = 2.5 minutes.

Table 1 shows the critical connections and traffic unit meter readings for an average duration of 2.5 minutes for the case of full availability, and Table 2 shows similar values for the case of gradings serving third and subsequent 10-contact selectors, *i.e.*, where the traffic may be assumed to be pure chance.

TABLE 2.

No. of Switches.	Traffic Unit Meter Reading.	Congestion Meter Reading.	No. of Switches.	Traffic Unit Meter Reading.	Congestion Meter Reading.
10	3.62	0.72	40	11.54	2.31
11	3.96	0.79	45	12.60	2.52
12	4.28	0.86	50	13.64	2.73
13	4.60	0.92	55	14.65	2.93
14	4.92	0.98	60	15.62	3.12
15	5.23	1.05	65	16.57	3.31
16	5.53	1.11	70	17.47	3.49
17	5.83	1.17	75	18.30	3.66
18	6.13	1.23	80	19.09	3.82
19	6.42	1.28	85	19.84	3.97
20	6.71	1.34	90	20.59	4.12
25	8.05	1.61	95	21.33	4.27
30	9.26	1.85	100	22.03	4.41
35	10.44	2.09			

Note :—Average duration = 2.5 minutes.

When comparing the meter readings obtained in practice with the values determined theoretically for a 1 in 200 loss, it is necessary to average the former over a period dependent upon the size of the group of switches and to omit from the average, all values which are due to known or suspected faults. The result will then give a fairly reliable indication of the condition of the service on the particular route. These readings are usually further compared with the results of traffic records before any definite action is taken. This is of course necessary to guard against (a) unevenness in the distribution and (b) a greater smoothness or peakiness of traffic than is allowed for by the design tables.

(B) As an extension of the above application it became necessary quite recently to determine the critical connections and traffic unit meter readings for the peculiar case of gradings of outlets from 25-point uni-selectors.* This type of switch is used in the Middlesboro' and Hanley satellite exchanges.

The useful information available consisted of a series of values of traffic offered to the 25th

* *This is the B.E.S.A. term for what was formerly known as preselector or its equivalent.*

choice in a full availability group for various values of total traffic. It was required to determine the 25th contact traffic. The following method was adopted:—

From expression (11) traffic offered to 25th contact $= \frac{P_x \times 25}{1 - P_x}$ where P_x is the proportionate loss at the 25th contact.

But traffic offered to 25th contact = traffic carried by 25th contact + traffic offered to 26th contact.

Knowing the value of the traffic offered to 25th contact the value of P_x can be determined, and from it the value P_xA which is the traffic offered to the 26th contact for the given value of total traffic A.

As an example, for a total traffic of 18 traffic units offered to a full availability group, it is known that

traffic offered to 25th contact = 0.6346 traffic unit.

$$\text{Hence } 0.6346 = \frac{P_x \times 25}{1 - P_x}$$

$$\text{from which } P_x = \frac{0.6346}{25.6346}$$

and P_xA = traffic offered to 26th contact

$$= \frac{18 \times 0.6346}{25.6346}$$

$$= 0.4456 \text{ traffic unit.}$$

Hence traffic carried by 25th contact

$$= 0.6346 - 0.4456$$

$$= 0.189 \text{ traffic unit.}$$

A series of values was obtained and curves plotted showing the relation between total traffic and lost traffic, and traffic carried by 25th contact and total traffic. From these the values of last contact traffic for different sizes of groups at a 1 in 200 grade of service were obtained and, finally, the critical connections and traffic unit meter readings in the same manner as before.

2. *Suggested Uses.*

(*a*) It has been shown that for both graded and full availability groups

$$\text{last contact traffic} = \text{loss} \left[\frac{x}{(A - \text{loss})} - 1 \right]$$

where x and A for the case of grading refer to the equivalent full availability traffic.

The above expression can be written

$$\text{Congestion call meter reading} = \text{overflow meter reading} \left[\frac{x}{(A - \text{loss})} - 1 \right] \quad \ldots\ldots(15)$$

If now the lost traffic is negligible compared with A, then (15) reduces to

$$\text{Congestion call meter reading} = \text{overflow meter reading} \left[\frac{x}{A} - 1 \right]$$

$$\text{or } A = \frac{\text{overflow meter reading} \times x}{(\text{congestion meter} + \text{overflow meter}) \text{ readings}} \quad \ldots\ldots(16)$$

In the case of graded groups within the limits given on a previous page this will become

$$\text{Congestion call meter reading} = \text{overflow meter reading} \left[\frac{N}{A'} - 1 \right] \quad \ldots\ldots(17)$$

Expressions (15)-(17) have been derived by utilising the assumption that the average holding time of a last choice call would be equal to the average holding time of an overflow call if it had been effective.

If, therefore, we record readings on both congestion and overflow meters for a reasonable length of time, we can determine approximately what traffic is being carried by a group of switches.

As an example—the following figures have been extracted from an early traffic record and the value of A deduced and compared with the actual value.

Average congestion meter reading = 1.2
,, overflow ,, ,, = 0.6
$x = 8$

$$\text{Hence } A = \frac{\text{overflow meter reading} \times x}{\text{congestion} + \text{overflow meter readings}}$$

$$= 2.66 \text{ traffic units.}$$

The actual value was 2.44 traffic units.

As an illustration of the results obtained when applied to a grading we have,

Average congestion meter reading = 4.9
,, overflow ,, ,, = 8.9
$N = 15$

$$\text{Hence } A' = \frac{\text{overflow meter reading} \times N}{\text{congestion} + \text{overflow meter readings}} = 9.6 \text{ traffic units.}$$

The actual value was 9.24 traffic units.

Comparing this with a full availability group, it is seen that

$$4.9 = 8.9 \left(\frac{x}{A} - 1 \right) \text{ where } x = 10$$

or equivalent full availability traffic A = 6.4 traffic units.

Fig. **2** shows that the lost traffic will be 0.385 traffic unit. When the value of lost traffic is 0.385, the curve in Fig. **5** shows that the total traffic for the graded group will be 9.25 traffic units.

(*b*) The present method of recording the traffic carried by a group of switches is to determine, either manually or automatically, the total number of simultaneous engagements of switches within the group at stated intervals and to divide the total by a factor dependent upon the frequency of the readings and duration of the record.

This method, except in specified cases, only gives the traffic carried by each shelf of switches and has no regard to the distribution of traffic over the grading, actual grade of service or to the type of traffic passing the group.

If we can measure accurately the traffic carried by the last choice in any group of switches, it is quite easy to determine from curves the total traffic being carried and the grade of service. Since, however, the last contact traffic is generally quite small, the effect of small inaccuracies will be great in the final result and it is therefore more desirable to record the traffic carried by an earlier choice. Dependent upon the grading the first " common " or two " partial commons " should be selected and the traffic recorded on these. In the latter case any unevenness in distribution will be shown. In these cases the traffic carried will be greater and small inaccuracies will not affect the result to any great extent. The values of total traffic and grade of service could then be determined from curves. Figs. **2** and **4** show the relation between traffic offered to 11th contact and total traffic, and traffic carried by 10th contact and total traffic, which are examples of the type of curves used for graded groups of 10 contact switches.

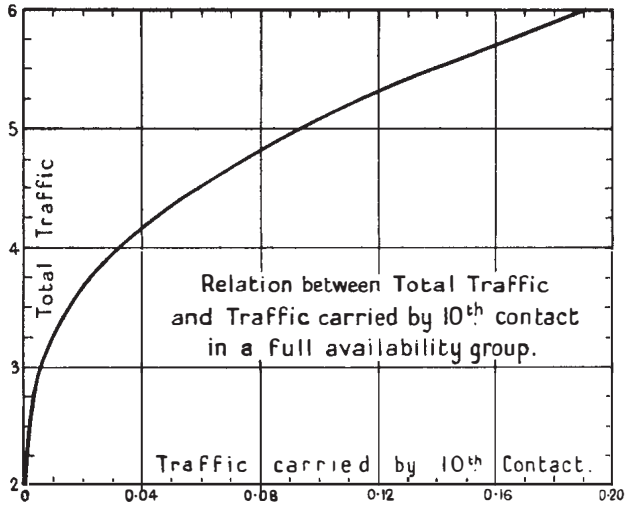


FIG. **4.**

The following are illustrations of the method both for full availability and graded groups.

The third choice in a full availability group of three outlets carried 0.14 traffic unit when the total traffic carried was 1.03 traffic unit. Curves, which are not illustrated, showed that if 1.00 traffic unit was offered to three circuits the third would carry 0.14 traffic unit.

As examples of the application of the principles to grading, results have been extracted from various traffic records available and the steps made are given in tabular form in Table 3.

TABLE 3.

No. of circuits.	Actual Traffic Carried.	Last Contact Traffic.	Values obtained from curves.		
			Traffic A.	Lost Traffic.	Theoretical Traffic A.
15	6.05	0.05	4.44	0.037	6.4
31	10.83	0.04	4.16	0.025	12.0
71	30.1	0.06	4.6	0.055	30.0

In preparing this table use has been made of Fig. **5**, which shows the relation between lost traffic and total traffic for various sizes of groups of 10 contact switches, where the traffic may be assumed to be pure chance.

The close agreement between actual and theoretical values depends entirely upon an even distribution of traffic, an event which at the present time is realised on most of the groups in exchanges due to an efficient maintenance of the required service conditions.

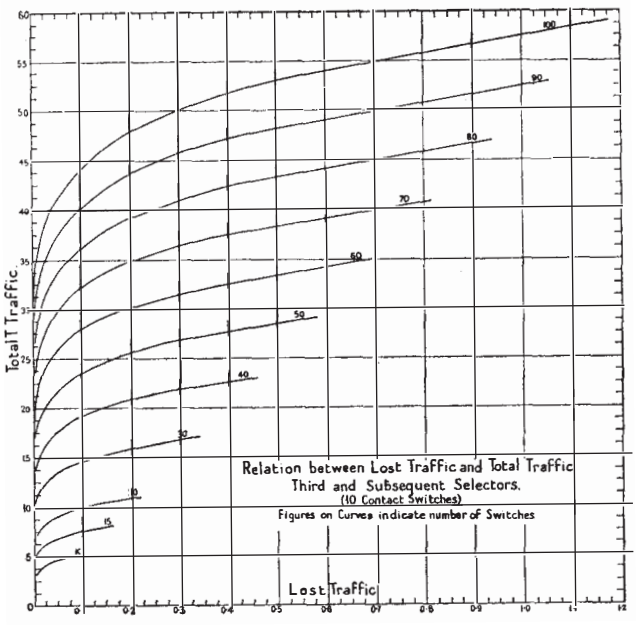

Total Traffic
Lost Traffic
Relation between Lost Traffic and Total Traffic
Third and Subsequent Selectors.
(10 Contact Switches)
Figures on Curves indicate number of Switches

FIG. 5.

(*c*) The third suggested use is mainly applicable to artificial traffic tests and other cases where the grade of service given when a certain quantity of traffic is being passed through a group is required approximately. For example, we may be passing four traffic units through a group of nine circuits fully available. It is known that 3.96 (approximately four) traffic units offered to a group of 10 circuits gives a grade of service of 1 in 200.

Expression (11) repeated gives,

$$\text{traffic offered to } x\text{th switch} = \frac{P_x \times X}{1 - P_x}$$

Substituting $x = 10$ and $P_x = 0.005$

$$\text{traffic offered to 10th switch} = \frac{10}{199}$$

Hence, grade of service of group of nine circuits with a traffic of 3.96 traffic units =

$$\frac{199 \times 3.96}{10} = \frac{1}{79}$$

The grade of service with a traffic of four traffic units would be approximately 1 in 75.

Carrying the case a little further by applying similar principles to a graded group of availability 9. Such odd availabilities are likely to be encountered in the trunking scheme for the Controller and Translator Bypath Systems. The author has selected the case of 14 traffic units offered to a group of 29 circuits with this availability. Design tables show that when this amount of traffic is offered to 30 circuits with an availability of 10 the grade of service is 1 in 200. With the same loss, namely, $\frac{14}{200} = 0.07$ traffic unit, curves show that the equivalent full availability traffic will be 4.78 traffic units. Using the previous nomenclature

$$BA = 0.07$$

$$\text{or } B = \frac{4.78}{0.07}$$

But expression (11) states that traffic offered to

$$\text{10th contact} = \frac{Bx}{1 - B} = \frac{\frac{0.07}{4.78} \times 10}{1 - \frac{.07}{4.78}} = \frac{0.7}{4.71}$$

This is the traffic lost from the 9th choice in the graded group and therefore grade of service

$$= \frac{0.7}{14 \times 4.71} = \frac{1}{94}$$

Conclusion.

The whole of the matter in this article has been based on pure chance traffic and therefore only applies to those cases where this type of traffic occurs in practice. The question of "smoothing effect" has hardly been broached, but it is felt that it would be difficult to derive methods based on theoretical principles which could be used in a similar manner to those given on earlier pages.

It is surprising, however, to what extent difficulties succumb to careful investigation and the author has no doubt that some reliable methods can be devised to cover the cases where smoothing effect is evident.

The comparison of the theoretical values with those obtained in practice, combined with the easy mathematical treatment, indicates that there is every possibility of determining, within a reasonable degree of accuracy, traffic values from comparatively little data.

In conclusion the most important expressions which have been derived and used are here recapitulated in which

x = the availability of a full availability or graded group.
A = traffic offered to a full availability group, or is the equivalent full availability traffic for a graded group.
N = number of switches in a graded group.
A′ = traffic offered to graded group.
P_x or B = grade of service for a full availability group.
B′ = grade of service for a graded group.

For a full availability group,

$$\text{last contact traffic} = P_x \left[\frac{x}{(1-P_x)} - A \right] \quad \ldots\ldots(7)$$

$$\text{last contact traffic} = P_x \left[x - A \right] \quad \ldots\ldots(10)$$

$$\text{traffic offered to last contact} = \frac{P_x x}{1-P_x} \quad \ldots\ldots(11)$$

For a graded group,

$$\text{last contact traffic} = \text{loss} \left[\frac{x}{(A-\text{loss})} - 1 \right] \quad \ldots(13)$$

$$\text{last contact traffic} = \text{loss} \left[\frac{N}{(A'-\text{loss})} - 1 \right] \quad \ldots(14)$$

with certain limitations as indicated in the text.

Application of traffic meter readings,

$$\text{Congestion call meter reading} = \text{overflow meter reading} \left[\frac{x}{(A-\text{loss})} - 1 \right] \quad \ldots\ldots(15)$$

$$A = \frac{\text{overflow meter reading} \times x}{(\text{congestion meter} + \text{overflow meter}) \text{ readings}} \quad \ldots\ldots(16)$$

$$\text{Congestion call meter reading} = \text{overflow meter reading} \left[\frac{N}{A'} - 1 \right] \quad \ldots\ldots(17)$$

with certain limitations as indicated in the text.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH SEPT., 1930.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileage.				Engineering District.	Underground Wire Mileage.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
691,262	527	3,945	54,060	132	London	25,066	93,233	2,630,931	76,189
92,459	2,228	21,549	71,255	2,212	S. Eastern.	4,094	64,679	279,638	36,043
95,433	4,523	32,648	67,466	3,875	S. Western.	22,198	18,777	207,548	66,445
77,341	6,325	39,550	71,105	7,037	Eastern.	24,932	49,716	166,315	61,165
109,226	9,589	45,532	67,387	4,687	N. Mid.	33,664	70,521	282,326	97,086
95,701	4,841	31,611	82,307	4,095	S. Mid.	13,927	33,446	234,524	78,647
63,487	4,417	30,061	60,647	3,843	S. Wales.	6,871	31,660	142,771	67,410
119,843	7,929	27,174	57,029	4,416	N. Wales.	13,628	43,822	326,188	57,229
172,826	1,443	16,036	45,285	3,085	S. Lancs.	14,919	88,705	550,222	67,845
102,838	6,065	30,907	51,039	3,183	N. Eastern	14,727	52,421	283,006	70,212
70,025	3,888	24,089	41,680	2,743	N. Western.	7,968	37,880	180,983	42,375
53,010	2,481	15,916	27,896	3,260	Northern.	8,169	22,483	147,262	37,055
24,221	4,434	9,071	15,173	618	Ireland N.	135	3,161	52,198	2,406
73,877	4,733	27,714	42,982	1,324	Scotland E.	7,561	18,071	160,961	38,713
96,320	7,241	24,955	46,632	1,247	Scotland W.	11,776	30,191	246,301	34,083
1,937,869	70,664	380,758	801,943	45,757	Total	269,635	658,766	5,900,174	832,924
1,918,248	70,998	378,481	789,730	44,811	Figures as at 30th June, 1930.	205,363	639,313	5,798,285	841,130

POWER DISTRIBUTION IN AUTOMATIC TELEPHONE EXCHANGES.

S. A. WICKERSON,
Engineering Department,
Automatic Telephone Manufacturing Co., Ltd.

IN Strowger Automatic Telephone Exchanges where the familiar Line Switch Units and Selector Trunk Boards are installed, the method of power distribution employed is mainly by means of main bus bars or feeder cables from the Power Board to a number of Feeder Bus Boards located in centralised positions in the automatic equipment rooms. From these points numerous pairs of V.I.R. distribution cables are provided, generally on the basis of one set of feeders per ten Line Switch Units or three Selector Trunk Boards. Fig. **1** shows the rear of a Feeder Fuse Board with its associated power cabling.

This system of power distribution was the best which could be evolved when a method of mounting automatic equipment involving many different types of racks of varying sizes both in height and floor area was used.

It necessitated the supply of various sizes of power cables, cable runway, feeder fuse boards, spare fuse cabinets; also installation work was a rather slow process, involving many soldered joints at terminating lugs.

With the adoption of open type racks as standard for British Post Office exchanges, a new system of power distribution evolved by the A.T.M. Coy. will be installed for the first time in this country at Bristol Central Exchange. Comparison with other schemes, where feeder fuse boards are used, will then be possible.

Bus bar work has been previously used in the power and battery rooms of telephone exchanges, also up to the feeder fuse boards in the automatic equipment rooms, and it is an extension of the principle of using bus bars for power distribution instead of V.I.R. power cables with which this article is concerned.

Fig. **2** illustrates a method of linking the end cells of a battery together using bus bars, all joints being treated with vaseline and then clamped.

Figs. **3** and **4** are front and rear views of a telephone power board showing the laminated bus bar work to the feeder fuse boards, etc. The bus bars shown in Figs. **3** and **4** will now

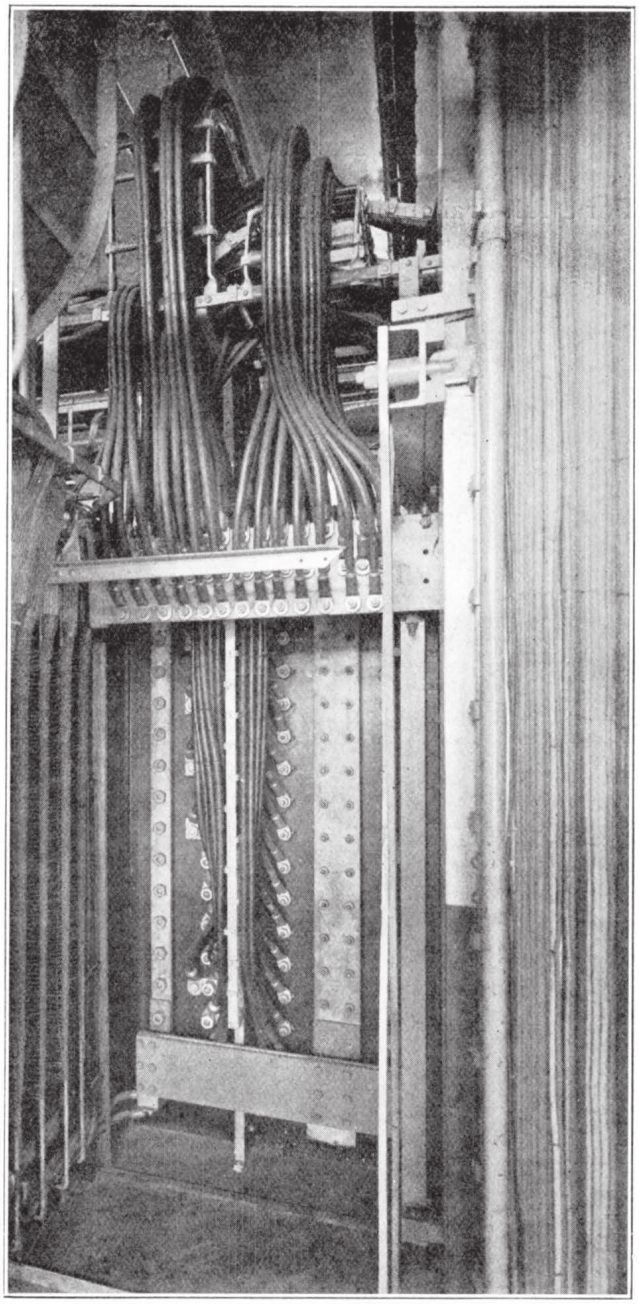


FIG. 1.

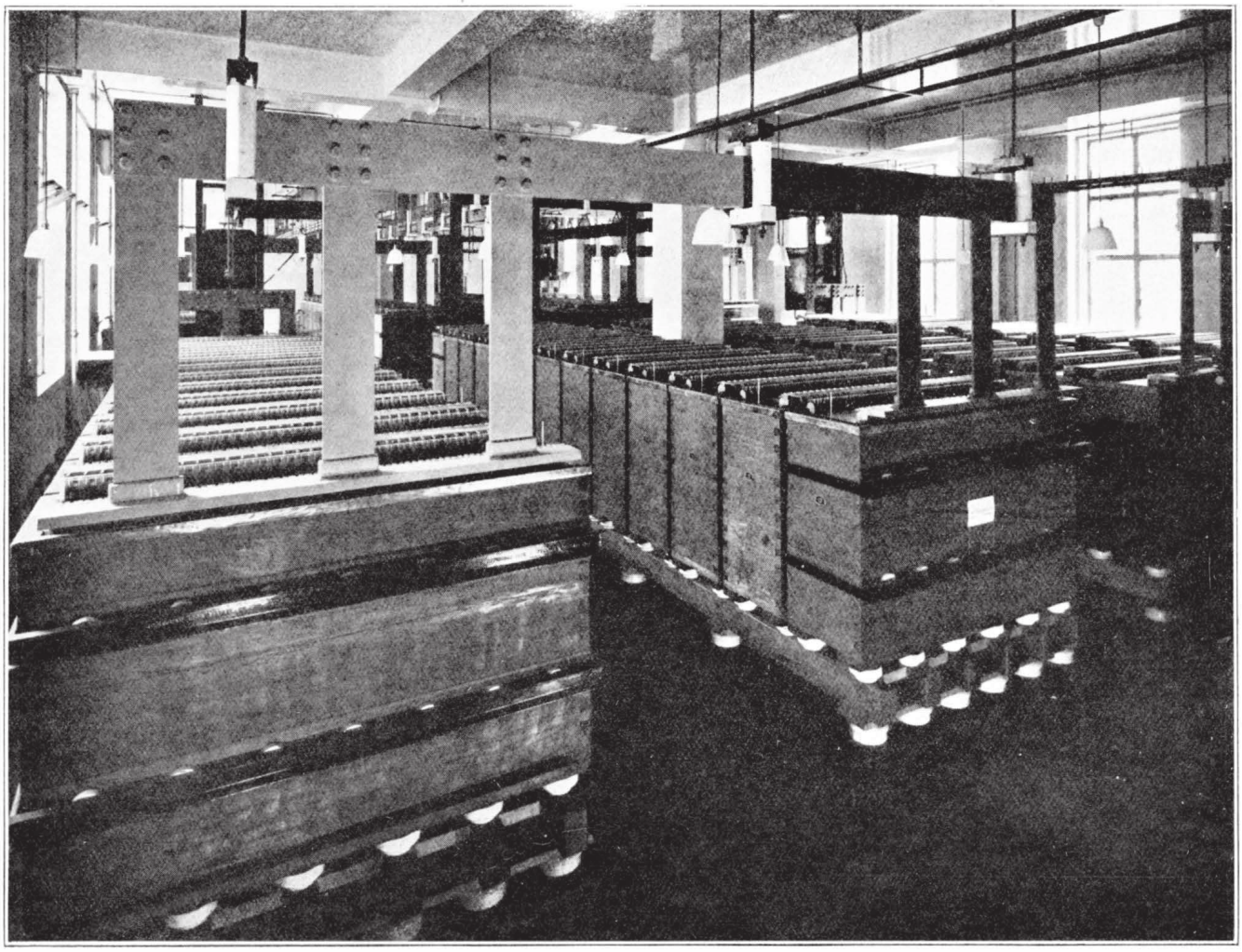


FIG. 2.

terminate on the main bus bars feeding the suites of racks as illustrated in Fig. **5**.

This photograph shows suites of automatic equipment racks of standard height and width, with the main feeder bus bars running transversely along the top of the end racks.

Inter-rack bus bars, illustrated in Fig. **6**, are connected to the mains as shown in Fig. **10**, which in turn are clamped to the individual automatic equipment rack bus bars running vertically at the left hand side of each rack, see Fig. **7**.

The route of the main bus bars feeding the suites of racks is shown in Fig. **8**, which is a plan of the apparatus room at Bristol Central Exchange. Telephone exchanges at Buenos Aires and Victoria, B.C., have already been equipped in this manner.

Three main sets of feeder bus bars are indicated by the thick chain dotted line, each set of mains feeding the suites of associated equipment.

From Figs. **9** and **10** it will be seen that the main bus bars, which may be of 1-2 or 3 laminations as required, are supported by robust bobbin type porcelain insulators carried on steel posts screwed in to the rack uprights. All joints in the bus bars are treated with vaseline and then clamped, and it is found that the resistance of a well-made joint of this type is less than that of a continuous bar of the same cross-sectional area. The surfaces of the bus bars to be jointed are cleaned with emery cloth under a coating of vaseline, removing any oxide and preventing further oxidisation before clamping the joint.

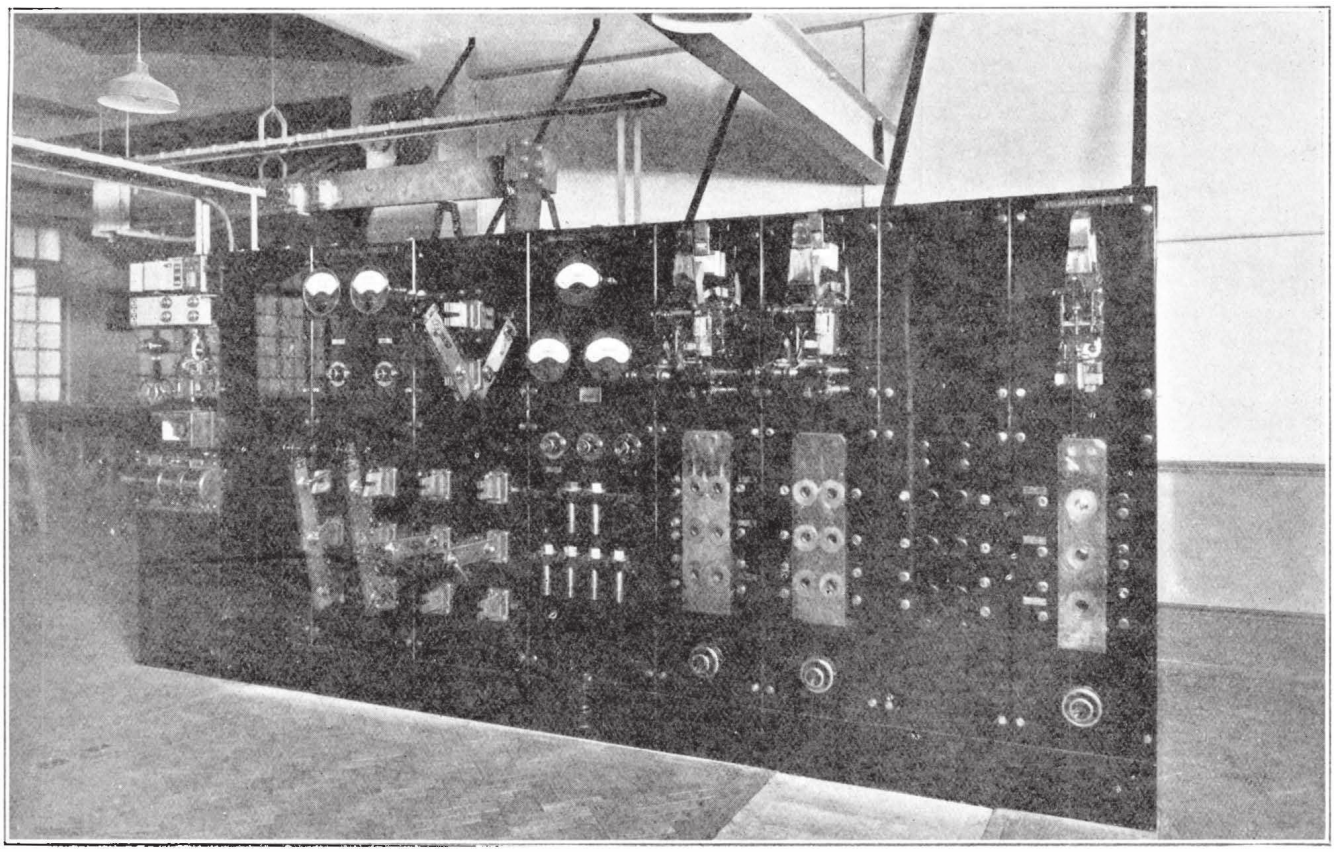


FIG. 3.

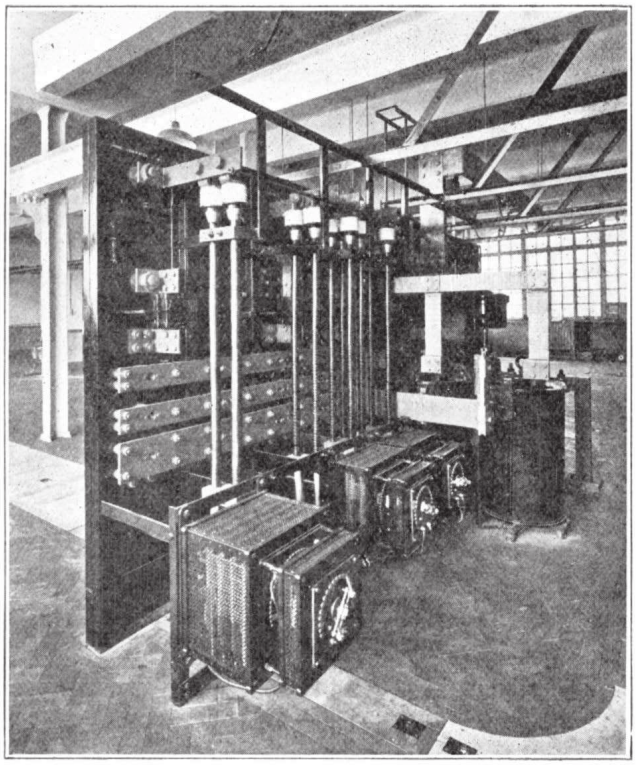


FIG. 4.

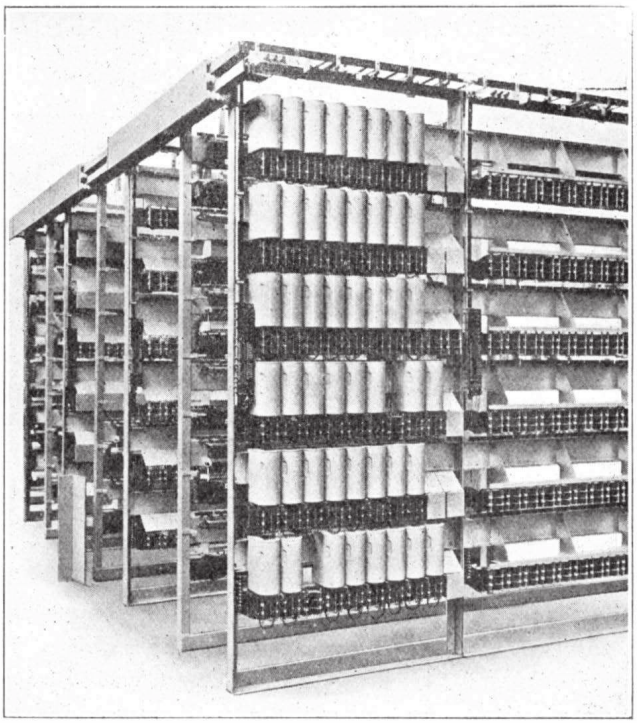


FIG. 5.

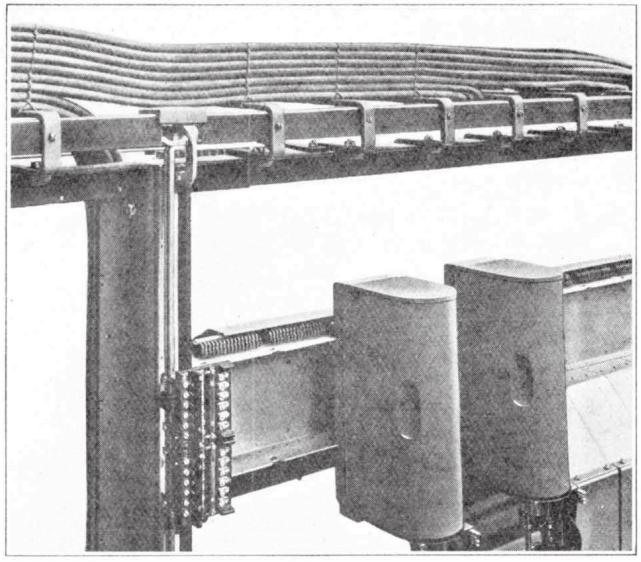


FIG. 6.

The bus bars are stock material, undrilled and can be graded along the suites of racks as required by the current drain.

When an exchange is only partially equipped, sufficient material is furnished in the main conductors to provide for the initial requirements, further laminations being added as the exchange grows.

The bus bar cross-sections are calculated in accordance with the formulæ evolved by Mr. A. Prado, A.M.I.E.E., of the Automatic Telephone Manufacturing Company, Ltd., and which were published in "Telephony," dated 14th, 21st and 28th December, 1929, under the heading—"Laws of Potential Drop in Conductors." The purpose of the article describing the formulæ was to outline methods whereby power distribution schemes could be designed with a minimum mass of metal. In order to avoid unnecessary repetition of the various formulæ, reference should be made to the issue of December 28th of the foregoing publication in which will be found the general method of calculation.

The main bus bars are protected from accidental damage with simple pressed steel rear and front covers.

Figs. **9** and **10** show in detail the main and inter-rack bus bars, method of clamping joints, porcelain insulators, covers, etc., the upper bars being negative and the lower positive potential. The brackets supporting the inter-rack bus bars also carry the switchboard cables feeding the suite of racks.

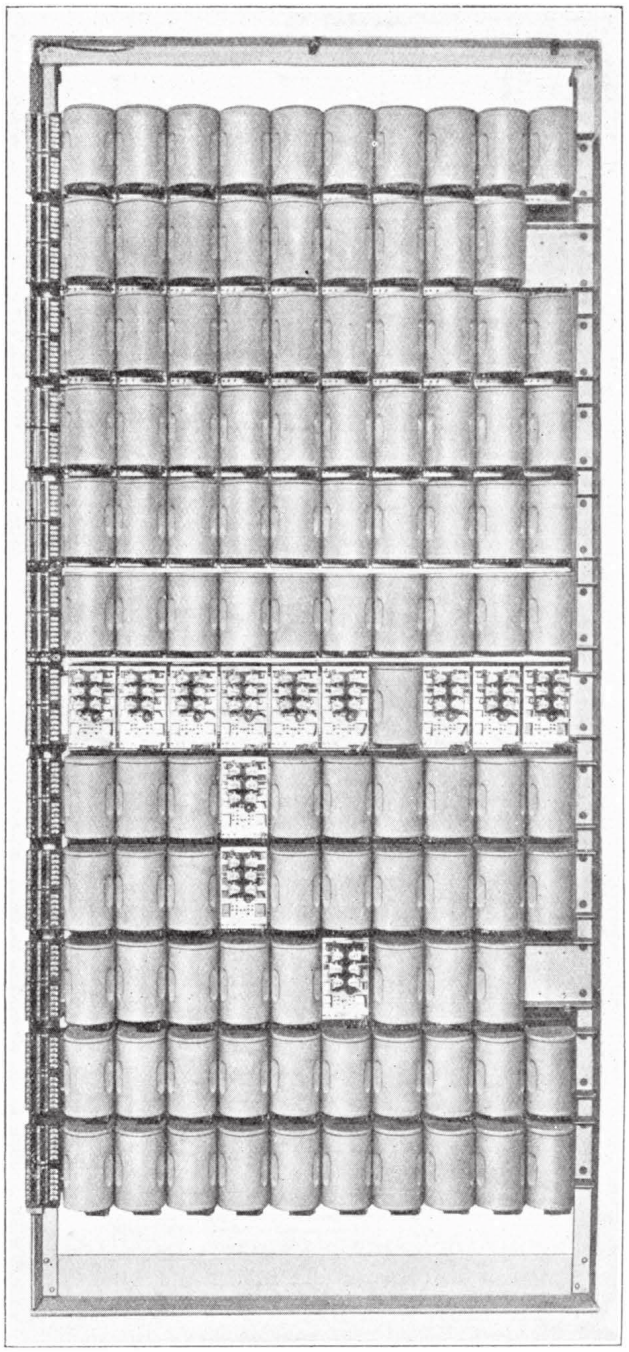


FIG. 7.

For protection and isolation purposes a small circuit breaker of the overload type rated at 75 amps. is provided for each suite of equipment, with facilities for extending an alarm into the main alarm system of the exchange in the event of a circuit breaker tripping for any reason such

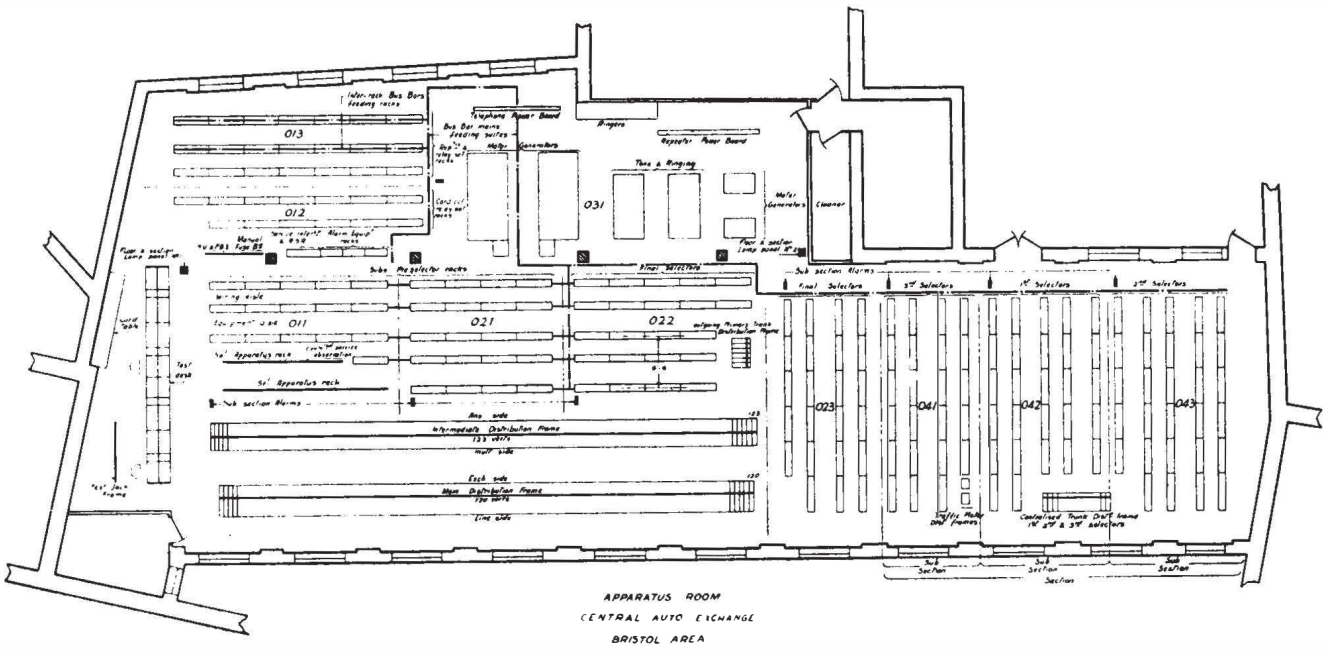


FIG. 8.

as an accidental short-circuit or temporary overload. The circuit breakers are also equipped with a delay device, causing the breaker to delay operation in a similar manner to the fusing characteristics of a power fuse.

The position of the exchange alarm lamps is indicated in Fig. **8** and it will be seen that upon a circuit breaker tripping through any cause, sub-section, section and floor lamps will glow; the usual audible indications will also be given. Upon the Maintenance Officer proceeding to the sub-section affected, the position of the circuit-breaker handle will indicate which circuit-breaker has tripped.

The maximum allowable voltage drop between the battery and the automatic equipment is one volt; therefore, as the internal resistance of the circuit-breaker is measured at .0012 ohm a saving in the size of the conductor necessary will be possible when it is realised that the internal resistance of a feeder fuse used in the old system ranged between .1 ohm and .2 ohm.

The inter-rack bus bars are standardised at $\frac{3}{4}'' \times \frac{1}{4}''$ and are supported inside the cable slats which are in turn clamped to the top angle of the equipment racks. Fig. **10** shows the bus bars between racks connected to the mains, the negative feed passing *via* the circuit-breaker. The negative and positive bus bars are cleated

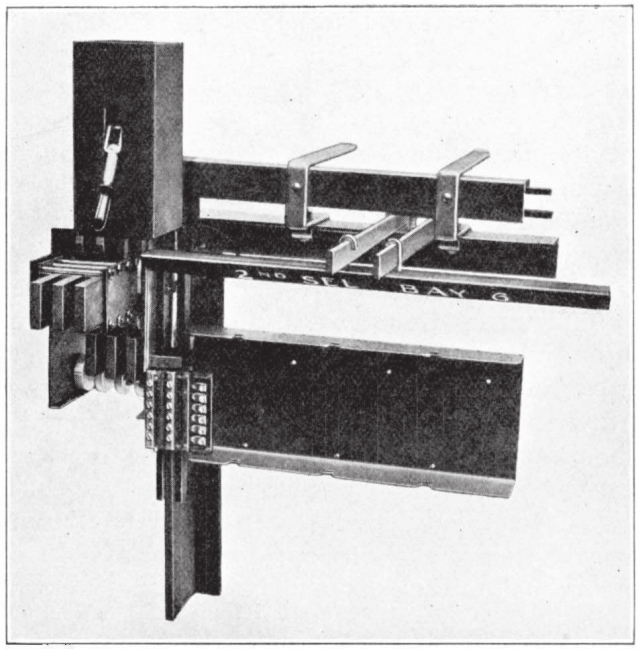


FIG. 9.

to the cable slats and protected with sheet steel covers.

In exchanges having a battery capacity of 1000 a.h. and under, suite circuit-breakers are not provided, the main circuit-breaker giving the necessary protection.

It will be noticed in Fig. **6** that the rack

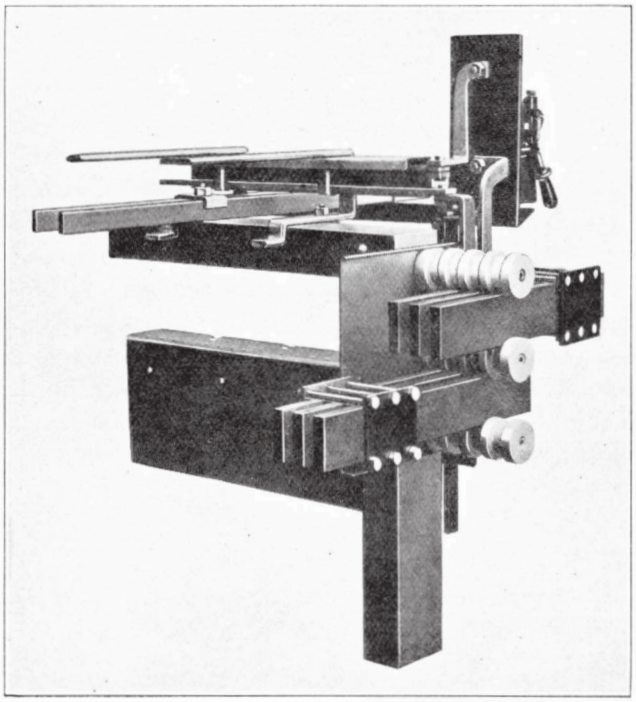


Fig. **10**.

positive bar is clamped directly on to the positive inter-rack bar, whilst it is necessary to provide an insulated link between the negative rack and inter-rack bus bars. Joints in bus bars have been eliminated as far as possible and where they do occur lock nuts are provided.

At the junction of adjacent racks a porcelain insulator is furnished as shown in Fig. **6**.

The bus bar arrangement on the equipment racks is shown in Fig. **7** and consists of two sets of duplicate $\frac{1}{4}'' \times \frac{1}{4}''$ bars, spaced $\frac{1}{4}''$ apart. This scheme allows the utmost flexibility with regard to the positioning of the unit type fuse panels, also obviating the drilling of the vertical bus bars. The rack bus bars are supported from the rack uprights and the fuse panels clamped to the bars where required. The requisite amount of strength is thus obtained for the supporting of the fuse panels, also the cross-section of the bus bar material provides for the maximum current drain of any automatic equipment rack.

A cross-section of the inter-rack bus bars is illustrated in Fig. **11**, exposed portions of the negative rack or inter-rack bus bars being protected with split bakelite tube, which is sprung over the bus bar as shown. This occurs between rack fuse panels, etc.

Adequate protection is thus provided, it being practically impossible to effect an accidental short-circuit.

The material used as a conductor in this all bus bar system of power distribution is aluminium, the reasons for employing this instead of copper are mainly engineering.

Aluminium as a conductor is approximately half the weight of a copper bar of equal resistance, and as the weight of the conductors in the power distribution system of a large telephone exchange is considerable, this is a definite advantage. The cross-sectional area will be greater than that of a copper bar carrying an equivalent current value to the extent of 61%, but this is no serious disadvantage.

Installers will find it easier to handle than copper; bending, drilling and filing operations, etc., being much easier.

With the standardised automatic equipment racks now provided in telephone exchanges, allowing a uniform lay-out as shown typically in Fig. **8** an all bus bar system of power distribution as described in this article is possible.

Distribution circuit-breakers can be replaced immediately in the event of temporary overloads occurring, instances of this being actually recorded during periods of abnormal traffic.

Feeder fuse boards, V.I.R. distribution cables and cable runway, etc., are eliminated and the process of installation considerably simplified.

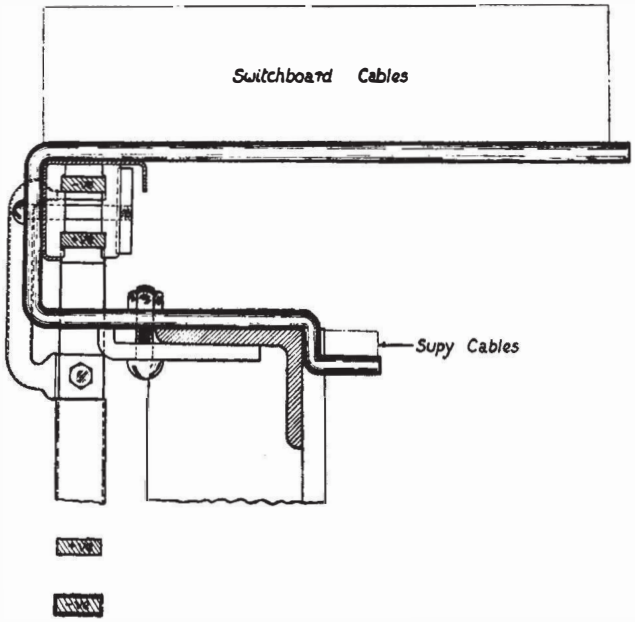


Fig. **11**.

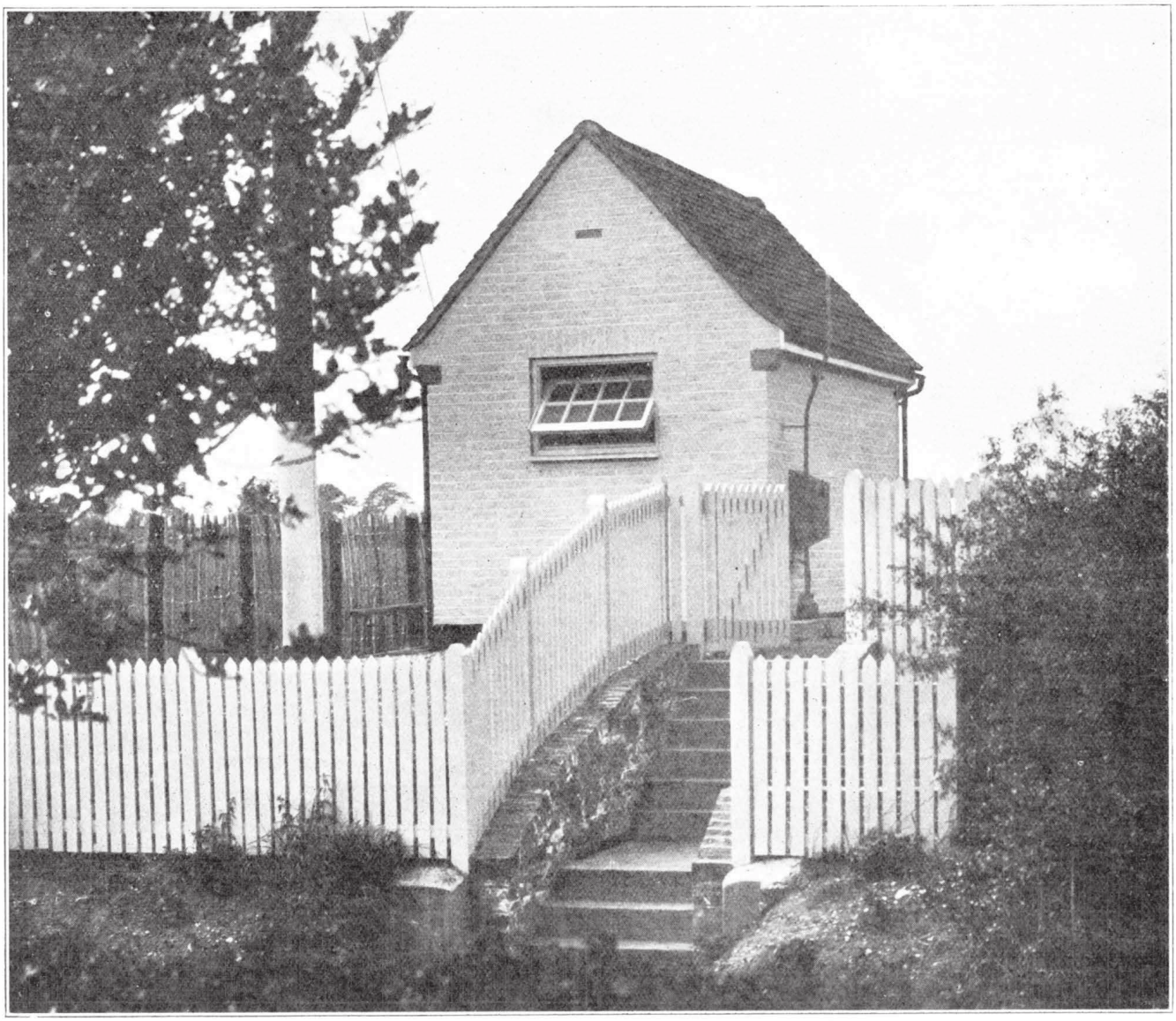
FROM ST. MABYN TO DRUMLITHIE.

J. C. Dallow.

THE infant of the telephone service grows to adolescence. Barely two years of age, it has, in its truly remarkable and unparalleled progress, journeyed over the whole country, from tiny hamlets in the Devon valleys to the barren moors of Inverness.

The infant referred to is the Rural Automatic Exchange. As its name implies, this type of equipment caters for sparsely populated districts in which only a small number of subscribers scattered over a wide area can be obtained.

A detailed technical description of the system was given in the July, 1929, issue of this Journal, and therefore it will be unnecessary to do more than refer to the salient features of the scheme in this account of its progress.



Photograph by Dallow.

Fig. 1.—A typical brick R.A.X.

Installation Procedure.

Exchanges are opened when a minimum of eight applications for service have been signed. In order that the prospective subscribers shall be given service with the least delay, every stage of the work from the acquisition of the land to the opening of the exchange is carried through as expeditiously as possible.

Upon authorisation of an exchange, instructions are issued to the engineering section concerned to obtain an offer of a suitable site on which to erect the building. Local officers have become adept in negotiating for the small plots of land required for this purpose. When the site has been chosen, a detailed report with plans is furnished to Headquarters and, if approved, the land is bought by the Post Office. The legal negotiations usually occupy a few weeks, and during this period tenders for the standard type of building are invited from local builders and held until legal possession of the site is granted. Immediately possession is obtained, the building contract is placed and the erection of the building proceeds under the supervision of the Sectional engineer.

The building may be either of brick or of stone, but the general construction and dimensions (14′ × 7′ 7″ × 9′ high internally) are standard for all exchanges. Typical brick and stone buildings are shown in Figs. **1** and **2** respectively.

While the building is in course of construction, the external line work is put in hand and the internal equipment is obtained. The latter consists of one or more automatic units and the power plant. Each automatic unit contains switching equipment for 25 lines, together with a ringing vibrator, tone generator and other

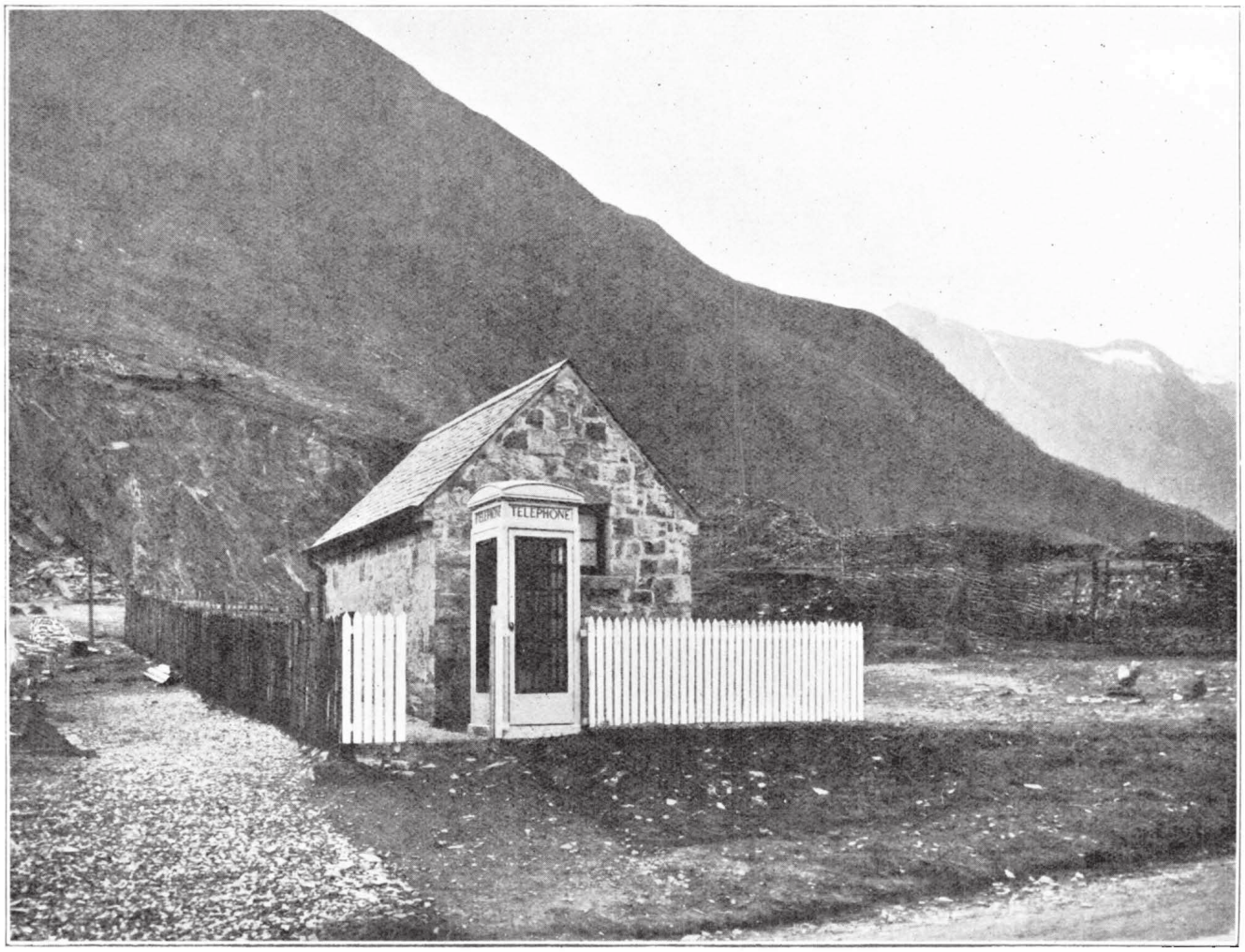


Fig. 2.—A stone R.A.X. The snow-lined hills on the right guard the entrance to Glencoe.

common apparatus. A unique feature of the unit is that all the equipment is enclosed in a steel double walled air-spaced cabinet in order to make the interior as damp-proof and dust-proof as possible. Not more than four units can be fitted, so that the maximum capacity of an exchange in a standard building is 100 lines. In most cases the power plant comprises a 1 H.P. petrol engine coupled to a small generator; two sets of 50 volt 40 amp. hour secondary cells and a small charging control panel are also provided.

After completion, the building is allowed to dry out for a week or two, and installation of the equipment proceeds. The batteries and power plant are fitted first, followed by the automatic units.

Installation of the subscribers' telephones and the apparatus at the distant ends of the junctions is undertaken while the exchange is being fitted. When all is completed, a test of the whole equipment is carried out and the exchange is brought into service.

Establishment Period.

It will be readily understood that the establishment of an exchange, including all phases of the development from the selection of a wayside plot of virgin soil to the testing out of the equipment, demands foresight and co-ordination at every step in order to attain the minimum overall period. The average period for providing an R.A.X. from the commencement of site search to the opening date is just over seven months. This average takes into account a number of cases in which the legal negotiations for the land have been protracted, and others which have been delayed by the erection of buildings specially finished to harmonise with the amenities of the surroundings. The record time stands at $4\frac{1}{2}$ months, this being attained in several instances.

Progress of Scheme.

The first few R.A.X's were opened in the spring of 1929. Since then, the development has proved that there has been a large number of potential subscribers in country districts waiting for the introduction of a telephone system capable of solving the difficulties associated with rural manual systems. Indifferent operating, absence of night service, non-secrecy and many other obstacles are swept aside by the R.A.X., the result being that 300 exchanges have been brought into service in less than two years. Approximately 75% are entirely new additions to the telephone system.

Such a phenomenal demand for these exchanges necessitates systematic working of all concerned and every stage of the work is therefore scrutinised with the object of bringing to light avoidable causes of delay. Legal work in connection with the site has been reduced to a minimum; a new standard building has been designed to obviate prolonged drying out; and modifications to the internal equipment are being introduced to lessen the installation work.

The attention given has been reflected in the results obtained. Early in 1929 exchanges were being opened at about three per month. This rate was steadily improved to 15 per month in the spring of 1930 and has been further increased until, for November, 1930, these exchanges have been brought into service at the rate of one per

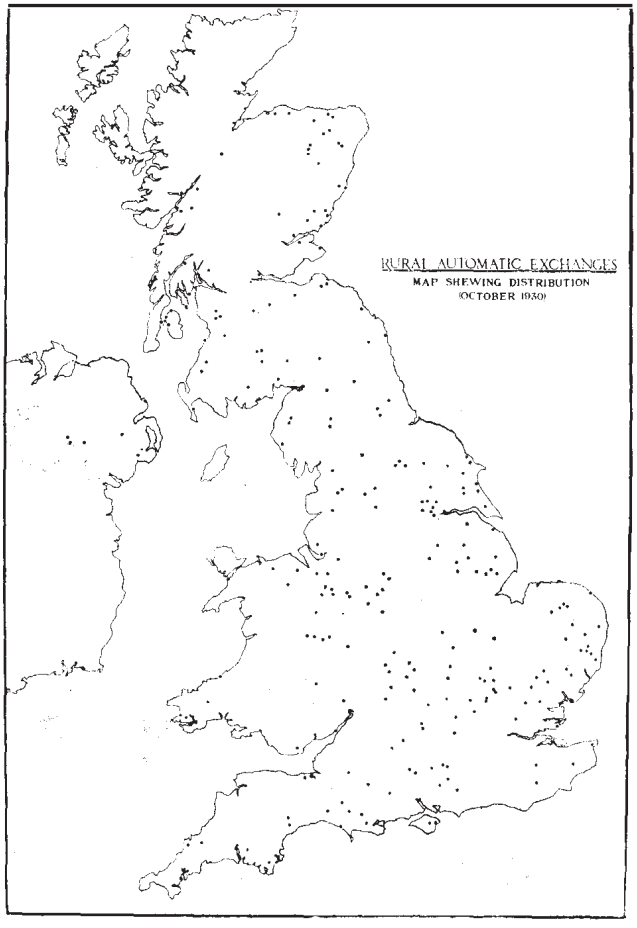


FIG. 3.—POSITIONS OF R.A.X's.

day. The opening of an R.A.X. has therefore become a daily habit in the Department.

A very encouraging feature is that in 35 of the exchanges already opened, the capacity of the initial equipment has been exhausted owing to increases in the number of subscribers, and additional automatic units have been fitted. This is concrete evidence of public satisfaction and confidence in the new system, even to personal recommendation of it.

Fig. 3 shows an outline map of the United Kingdom and indicates each exchange by a dot; a complete list of the exchanges opened to the end of November, 1930, is given in the Appendix to this article.

Statistics are usually of interest only to those immediately concerned. Schedules of names do not as a rule set the imagination wandering and are generally devoid of romantic interest. This list is an exception. The quaint names included are fascinating in themselves and their old-world flavour conjures up in one's mind picturesque villages nestling far from the roar of civilisation. It is not generally known that there is a Maze in Northern Ireland; Scotland has a Mouswald and an Eden. Hebron is in South Wales, while Essex can boast a Good Easter.

Visits to several of the exchanges have confirmed also that they are placed in beautiful surroundings. One forgives Llanfairtalhaiarn its name on seeing its grey stone cottages clustered on the hillside and the River Elwy threading its way through the meadows below.

Photograph by Dallow.

FIG. 4.—THE KIOSK ATTACHED TO A RURAL AUTO. EXCHANGE IN THE LONDON DISTRICT.

Walkern takes on a new interest when one has lunched in the village tavern, complete with old oaken beams, cavernous fireplace, pewter and brasses.

Fig. 4 shows the attractive locality in which the kiosk connected with Stapleford, the only R.A.X. in the London District, is situated. Indeed, the list can be taken as a wholesale introduction to those unspoiled parts of rural Britain

for which the tourist searches; a very pleasant holiday could be spent by taking extracts from the list and visiting the villages concerned.

Extension to 200 Lines.

The success of this type of exchange has prompted the development of an R.A.X. with a capacity of 200 lines. The possibility of future extension was visualised at the commencement of the original scheme, and all the sites obtained are large enough to allow for an increase in the length of the building to accommodate apparatus for 200 lines.

The first few exchanges employing the larger capacity equipment will be brought into service very shortly.

RURAL AUTOMATIC EXCHANGES.

(Installed up till the end of November, 1930, throughout the country)

No.	Exchange.	Parent Exchange.	Engineering Section.	District.	No. of Working Lines initially.	No. of Units fitted.	Date opened.
1	*Ramsay	Peterborough	Peterborough	N. Mid.	60	—	24-10-21
2	*Hurley	Maidenhead	Reading	S. Mid.	47	—	20-12-21
3	†Blockley	Moreton-in-Marsh	Gloucester	S. Wa.	23	—	25-3-24
4	‡Haseley Knob	Warwick	Coventry	N. Mid.	11	—	19-3-25
5	Haynes	Bedford	St. Albans	E.	12	1	4-2-29
6	Harbury	Leamington	Coventry	N. Mid.	13	1	26-2-29
7	North Stainley	Ripon	York	N.E.	12	1	11-3-29
8	Elsham	Brigg	Lincoln	N.E.	12	1	26-3-29
9	Hampton	Malpas	Shrewsbury	N. Wa.	14	1	8-4-29
10	Rendham	Framlingham	Colchester	E.	9	1	22-4-29
11	Collier St.	Paddock Wood	Tunbridge Wells	S.E.	9	1	23-4-29
12	Sinderby	Thirsk	York	N.E.	9	1	30-4-29
13	Weston	Letchworth	St. Albans	E.	15	1	1-5-29
14	Church Stoke	Welshpool	Shrewsbury	N. Wa.	9	1	6-5-29
15	Marbury	Whitchurch	Shrewsbury	N. Wa.	13	1	7-5-29
16	Walkern	Stevenage	St. Albans	E.	12	1	14-5-29
17	Longhoughton	Alnwick	Newcastle N.	N.	8	1	15-5-29
18	West Cranmore	Shepton Mallet	Exeter	S.W.	10	1	21-5-29
19	Clifton	Shefford	St. Albans	E.	30	2	22-5-29
20	Broughton	Kettering	Coventry	N. Mid.	9	1	28-5-29
21	Quainton	Aylesbury	Oxford	S. Mid.	11	1	30-5-29
22	Ellastone	Ashbourne	Leicester	N. Mid.	12	1	10-6-29
23	Otton	Ipswich	Colchester	E.	11	1	10-6-29
24	Aughnacloy	Armagh	Belfast	N. Ire.	12	1	11-6-29
25	Barrhill	Girvan	Glasgow S.	Scot. W.	9	1	20-6-29
26	Pipegate	Hanley	Stoke	N. Wa.	19	2	25-6-29
27	Ampleforth	Easingwold	York	N.E.	13	1	25-6-29
28	Crucorney	Abergavenny	Hereford	S. Wa.	13	1	25-6-29
29	Dunsop Bridge	Clitheroe	Blackburn	N.W.	12	1	25-6-29
30	Ardwell	Stranraer	Glasgow S.	Scot. W.	11	1	2-7-29
31	Islandmagee	Whitehead	Belfast	Ire. N.	12	1	5-7-29
32	Bridge of Cally	Blairgowrie	Dundee	Scot. E.	9	1	16-7-29
33	Pirnmill	Brodick	Glasgow N.	Scot. W.	8	1	16-7-29
34	Closeburn	Thornhill	Glasgow S.	Scot. W.	9	1	19-7-29
35	Welford-on-Avon	Stratford-on-Avon	Coventry	N. Mid.	12	1	23-7-29
36	Lumsden	Huntly	Aberdeen	Scot. E.	7	1	24-7-29
37	Newbrough	Hexham	Newcastle S.	N.	8	1	24-7-29
38	Mouswald	Dumfries	Glasgow S.	Scot. W.	9	1	26-7-29
39	Gamlingay	Sandy	St. Albans	E.	23	2	29-7-29
40	Cerne Abbas	Dorchester	Bournemouth	S.W.	8	1	30-7-29
41	Hampden Row	Gt. Missenden	Oxford	S. Mid.	10	1	30-7-29
42	Reepham	Lincoln	Lincoln	N.E.	9	1	6-8-29
43	Onich	Fort William	Glasgow N.	Scot. W.	10	1	6-8-29
44	Rhynie	Huntly	Aberdeen	Scot. E.	10	1	7-8-29
45	Slaidburn	Clitheroe	Blackburn	N.W.	16	1	13-8-29
46	Broadwindsor	Beaminster	Bournemouth	S.W.	9	1	13-8-29
47	Old Meldrum	Inverurie	Aberdeen	Scot. E.	29	2	14-8-29
48	Cayton Bay	Scarborough	York	N.E.	12	1	20-8-29
49	Catterline	Stonehaven	Aberdeen	Scot. E.	10	1	21-8-29

* Siemens Village Exchange. † A.T.M. Co. R.A.X. ‡ Relay Company's Equipment.

All others standard. (Auto Units No. 5.)

No.	Exchange.	Parent Exchange.	Engineering Section.	District.	No. of Working Lines initially.	No. of Units fitted.	Date opened.
50	Corpach	Fort William	Glasgow N.	Scot. W.	8	1	27-8-29
51	Chilbolton	Andover	Bournemouth	S.W.	9	1	3-9-29
52	Beattock	Moffat	Glasgow S.	Scot. W.	9	1	3-9-29
53	Abbotts Ann	Andover	Bournemouth	S.W.	11	1	5-9-29
54	Lorton	Cockermouth	Lancaster	N.W.	10	1	10-9-29
55	Llanfairtalhaiarn	Abergele	Bangor	N. Wa.	13	1	17-9-29
56	Abbotsbury	Weymouth	Bournemouth	S.W.	12	1	17-9-29
57	Coningsby	Horncastle	Lincoln	N.E.	20	1	17-9-29
58	Whitwell	Welwyn	St. Albans	E.	24	2	23-9-29
59	Brent Pelham	Bishop Stortford	Cambridge	E.	9	1	23-9-29
60	Long Sutton	Langport	Taunton	S.W.	10	1	1-10-29
61	Kilmaurs	Kilmarnock	Glasgow S.	Scot. W.	26	2	8-10-29
62	Terling	Witham	Colchester	E.	10	1	14-10-29
63	Badingham	Framlingham	Colchester	E.	9	1	14-10-29
64	Crossford	Carluke	Glasgow S.	Scot. W.	12	1	15-10-29
65	Tunstall	Kirkby Lonsdale	Lancaster	N.W.	8	1	22-10-29
66	Comberbach	Northwich	Stoke-on-Trent	N. Wa.	18	1	22-10-29
67	Brancaster	Hunstanton	Cambridge	E.	15	1	28-10-29
68	Hunmanby	Filey	York	N.E.	18	1	29-10-29
69	Lockeridge	Marlborough	Reading	S. Mid.	11	1	31-10-29
70	Toward	Dunoon	Glasgow N.	Sot. W.	8	1	1-11-29
71	Fenny Compton	Banbury	Oxford	S. Mid.	9	1	4-11-29
72	Auchengray	West Calder	Glasgow S.	Scot. W.	10	1	5-11-29
73	Banknock	Bonnybridge	Glasgow N.	Scot. W.	23	2	12-11-29
74	Laxton	Howden	York	N.E.	10	1	19-11-29
75	Lothersdale	Crosshills	West Yorks.	N.E.	9	1	19-11-29
76	Fundenhall	Wymondham	Norwich	E.	8	1	19-11-29
77	Kinnersley	Wellington	Shrewsbury	N. Wa.	9	1	19-11-29
78	Tysoe	Banbury	Oxford	S. Mid.	10	1	25-11-29
79	Kinlochleven	Fort William	Glasgow N.	Scot. W.	25	2	26-11-29
80	Longville	Church Stretton	Shrewsbury	N. Wa.	11	1	26-11-29
81	Bainbridge	Leyburn	Middlesborough	N.	8	1	27-11-29
82	Huxley	Torporley	Shrewsbury	N. Wa.	13	1	3-12-29
83	Machrie	Brodick	Glasgow N.	Scot. W.	11	1	3-12-29
84	Gerthleck	Inverness	Inverness	Scot. E.	8	1	5-12-29
85	Parwich	Ashbourne	Leicester	N. Mid.	10	1	10-12-29
86	Elton	Peterborough	Peterborough	N. Mid.	9	1	11-12-29
87	Gt. Tew (Oxon)	Chipping Norton	Oxford	S. Mid.	14	1	12-12-29
88	Great Alne	Alcester	Birmingham	N. Wa.	10	1	17-12-29
89	Carradale	Campbletown	Glasgow N.	Scot. W.	8	1	17-12-29
90	Ancroft	Berwick	Newcastle N.	N.	11	1	18-12-29
91	Bassingham	Lincoln	Lincoln	N.E.	10	1	20-12-29
92	Airth	Falkirk	Glasgow N.	Sc . W.	12	1	20-12-29
93	Wiseton	Retford	Lincoln	N.E.	12	1	20-12-29
94	East Allington	Kingsbridge	Plymouth	S.W.	10	1	23-12-29
95	Hollington	Uttoxeter	Stoke	N. Wa.	10	1	1-1-30
96	Kimpton	Welwyn	St. Albans	E.	23	2	6-1-30
97	Marrburn	Thornhill	Glasgow N.	Scot. W.	9	1	7-1-30
98	Aldbourne	Marlborough	Reading	S. Mid.	10	1	8-1-30
99	Worlington	Framingham	Colchester	E.	10	1	13-1-30
100	St. Osyth	Clacton	Colchester	E.	24	2	13-1-30
101	Fenwick	Kilmarnock	Glasgow S.	Scot. W.	23	2	14-1-30
102	Bassenthwaite	Cockermouth	Lancaster	N.W.	9	1	14-1-30
103	Inverkeilor	Arbroath	Aberdeen	Scot. E.	24	2	15-1-30
104	Kincaldrum	Forfar	Aberdeen	Scot. E.	9	1	20-1-30
105	Kilchattan Bay	Rothesay	Glasgow N.	Scot. W.	11	1	21-1-30
106	Long Sutton	Basingstoke	Guildford	S. Mid.	8	1	11-2-30
107	Bolton Abbey	Skipton	W. Yorks	N.E.	11	1	11-2-30
108	Hardwick	Worksop	Sheffield	N. Mid.	11	1	13-2-30
109	Denholme	Bradford	W. Yorks	N.E.	23	2	17-2-30
110	Riccall	Selby	W. Yorks	N.E.	11	1	18-2-30
111	Hanmer	Whitchurch	Shrewsbury	N. Wa.	10	1	18-2-30
112	Ashwell	Letchworth	St. Albans	E.	28	2	18-2-30
113	Benburb	Armagh	Belfast	N. Ire.	12	1	25-2-30
114	Normanby-by-Spital	Lincoln	Lincoln	N.E.	10	1	25-2-30
115	Morham	Haddington	Edinburgh (O)	Scot. E.	12	1	3-3-30
116	Rockbourne	Fordingbridge	Bournemouth	S.W.	8	1	4-3-30
117	Luss	Helensburgh	Glasgow N.	Scot. W.	9	1	4-3-30
118	Hartington	Buxton	Manchester	S Lancs.	25	2	4-3-30
119	Knowsley	Huyton	Liverpool	S. Lancs.	26	2	4-3-30
120	Bawdeswell	Dereham	Norwich	E.	13	1	4-3-30

No.	Exchange.	Parent Exchange.	Engineering Section.	District.	No. of Working Lines initially.	No. of Units fitted.	Date opened.
121	Manston	Ramsgate	Canterbury (E)	S.E.	17	1	4-3-30
122	Yardley Gobion	Stony Stratford	St. Albans	E.	22	2	11-3-30
123	Whiterashes	Dyce	Aberdeen	Scot. E.	10	1	11-3-30
124	Strachur	Dunoon	Glasgow N.	Scot. W	10	1	14-3-30
125	Homersfield	Bungay	Norwich	E.	8	1	17-3-30
126	Twinstead	Sudbury	Colchester	E.	12	1	18-3-30
127	Upton Grey	Basingstoke	Guildford	S. Mid.	21	1	18-3-30
128	Marshbrook	Church Stretton	Shrewsbury	N. Wa.	10	1	18-3-30
129	Dunlop	Kilmarnock	Glasgow S.	Scot W	16	1	18-3-30
130	Rillington	Malton	York	N.E.	17	1	25-3-30
131	Ash	Whitchurch	Shrewsbury	N. Wa.	9	1	25-3-30
132	Luthrie	Cupar	Dundee	Scot. E.	14	1	26-3-30
133	Boarhills	St. Andrews	Dundee	Scot. E.	10	1	26-3-30
134	Maze	Lisburn	Belfast	N. Ire.	13	1	31-3-30
135	Aldeby	Beccles	Norwich	E.	8	1	31-3-30
136	Topcliffe	Thirsk	York	N.E.	13	1	1-4-30
137	Rumford	Padstow	Plymouth	S.W.	9	1	7-4-30
138	Ballachulish	Oban	Glasgow N.	Scot. W.	18	1	8-4-30
139	Martin	Metheringham	Lincoln	N.E.	15	1	8-4-30
140	Ridgewell	Haverhill	Cambridge	E.	11	1	14-4-30
141	Privett	Petersfield	Guildford	S. Mid.	10	1	15-4-30
142	Clifford	Hay	Hereford	S. Wa.	10	1	15-4-30
143	Steele Road	Liddesdale	Edinburgh (Outer)	Scot. E.	10	1	16-4-30
144	Little Gaddesden	Boxmoor	St. Albans	E.	8	1	15-4-30
145	Glemsford	Sudbury	Colchester	E.	25	2	28-4-30
146	Wenvoe	Cardiff	Cardiff	S. Wa.	9	1	29-4-30
147	Dunure	Ayr	Glasgow S.	Scot. W.	12	1	29-4-30
148	Tow-Law	Bishop Auckland	Middlesbrough	N.	23	2	1-5-30
149	Charlton-on-Otmoor	Oxford	Oxford	S. Mid.	7	1	5-5-30
150	Good Easter	Chelmsford	Southend	E.	13	1	12-5-30
151	North Waltham	Basingstoke	Guildford	S. Mid.	24	2	13-5-30
152	Hale	Garston	Liverpool	S. Lancs.	27	2	13-5-30
153	Linley	Bishops Castle	Shrewsbury	N. Wa.	12	1	20-5-30
154	Watton	Driffield	York	N.E.	13	1	20-5-30
155	Aberlemno	Forfar	Aberdeen	Scot. E.	10	1	21-5-30
156	Morland	Penrith	Lancaster	N.W.	13	1	27-5-30
157	Kinlet	Kidderminster	Hereford	S. Wa.	8	1	27-5-30
158	East Langton	Market Harboro	Leicester	N. Mid.	10	1	29-5-30
159	Salmondsmuir	Carnoustie	Dundee	Scot. E.	10	1	29-5-30
160	Walcot	N. Walsham	Norwich	E.	10	1	2-6-30
161	Lochranza	Brodick	Glasgow N.	Scot. W.	9	1	3-6-30
162	Lea	Ross	Hereford	S. Wales	13	1	3-6-30
163	Callaly	Alnwick	Newcastle N.	N.	12	1	3-6-30
164	Ruhwith	Selby	York	N.E.	20	1	3-6-30
165	Wendling	Dereham	Norwich	E.	9	1	3-6-30
166	Mareham-le-Fen	Horncastle	Lincoln	N.E.	13	1	4-6-30
167	Sticknev	Boston	Peterborough	N. Mid.	11	1	4-6-30
168	Gt. Wakering	Southend	Southend	E.	38	2	4-6-30
169	Broadclyst	Exeter	Exeter	S.W.	22	2	10-6-30
170	Farnell	Montrose	Aberdeen	Scot. E.	9	1	11-6-30
171	Llanbryde	Elgin	Inverness	Scot. E.	8	1	16-6-30
172	Yetminster	Yeovil	Taunton	S.W.	12	1	17-6-30
173	Lower Guiting	Cheltenham	Gloucester	S. Wa.	16	1	17-6-30
174	Milbourne St. Andrews	Blandford	Bournemouth	S.W.	17	1	17-6-30
175	Bressingham	Diss	Norwich	E.	9	1	18-6-30
176	Gt. Bardfield	Halstead	Colchester	E.	20	2	23-6-30
177	Sacriston	Durham	Newcastle S.	N.	24	2	30-6-30
178	Inchture	Dundee	Dundee	Scot. E.	23	2	30-6-30
179	Hebron	Carmarthen	Swansea	S. Wa.	10	1	1-7-30
180	Clawdd Newydd	Ruthin	Bangor	N. Wa.	10	1	3-7-30
181	Stoke Fleming	Dartmouth	Exeter	S.W.	12	1	14-7-30
182	Drumlithie	Stonehaven	Aberdeen	Scot. E.	10	1	14-7-30
183	Alves	Elgin	Inverness	Scot. E.	18	2	15-7-30
184	Barr	Girvan	Glasgow S.	Scot. W.	11	1	15-7-30
185	Camblesforth	Selby	York	N.E.	11	1	15-7-30
186	Crossmichael	Castle Douglas	Glasgow S.	Scot. W.	11	1	8-7-30
187	Eccleston	Chester	Shrewsbury	N. Wa.	10	1	8-7-30
188	Kildrummy	Alford	Aberdeen	Scot. E.	8	1	10-7-30
189	Broadhaven	Milford Haven	Swansea	S. Wa.	13	1	22-7-30
190	Bovington Camp	Wareham	Bournemouth	S.W.	27	2	22-7-30

No.	Exchange.	Parent Exchange.	Engineering Section.	District.	No. of Working Lines. initially.	No. of Units fitted.	Date opened.
191	East Knoyle	Shaftesbury	Bournemouth	S.W.	12	1	28-7-30
192	Ochiltree	Cumnock	Glasgow S.	Scot. W.	13	1	29-7-30
193	Burn	Selby	York	N.E.	15	1	30-7-30
194	Hackleton	Northampton	Coventry	N. Mid.	11	1	30-7-30
195	Knock	Huntly	Aberdeen	Scot. E.	8	1	1-8-30
196	Stenton	East Linton	Edin. Outer	Scot. E.	11	1	5-8-30
197	Woodbury Salterton	Exeter	Exeter	S.W.	10	1	5-8-30
198	Doddington	Lincoln	Lincoln	N.E.	8	1	6-8-30
199	Johnston	Milford Haven	Swansea	S. Wa.	11	1	7-8-30
200	Gosforth	Whitehaven	Lancaster	N.W.	9	1	12-8-30
201	Moccas	Hereford	Hereford	S. Wa.	12	1	12-8-30
202	Eden	Banff	Aberdeen	Scot. E.	9	1	14-8-30
203	Etchingham	Hawkehurst	Tunbridge Wells	S.E.	25	2	18-8-30
204	Stapleford	Theydon Bois	London	London	15	1	18-8-30
205	Boreland	Locherbie	Glasgow S.	Scot. W.	10	1	19-8-30
206	Leconfield	Driffield	York	N.E.	14	1	19-8-30
207	Brading	Ryde	Southampton	S. Mid.	28	2	26-8-30
208	Auchterless	Turriff	Aberdeen	Scot. E.	8	1	26-8-30
209	Skipsea	Hornsea	York	N.E.	11	1	26-8-30
210	Hendre	Mold	Shrewsbury	N. Wa.	28	2	26-8-30
211	Lumphanan	Torphins	Aberdeen	Scot. E.	8	1	27-8-30
212	Ingrams Green	Midhurst	Guildford	S.Mid.	10	1	1-9-30
213	Copdock	Ipswich	Colchester	E.	37	2	1-9-30
214	King Edward	Turiff	Aberdeen	Scot. E.	8	1	2-9-30
215	Ash Bank	Hanley	Stoke-on-Trent	N. Wa.	10	1	2-9-30
216	Nether Stowey	Bridgwater	Taunton	S.W.	34	1	2-9-30
217	Ballygawley	Armagh	Belfast	N. Ire.	7	1	3-9-30
218	Elmsted	Ashford	Canterbury E.	S.E.	18	1	8-9-30
219	Ubbeston	Halesworth	Norwich	E.	9	1	8-9-30
220	Witton-le-Wear	Crook	Middlesboro'	N.	17	1	9-9-30
221	Whipsnade	Luton	St. Albans	E.	14	1	9-9-30
222	Spean Bridge	Fort William	Glasgow N.	Scot. W.	12	1	9-9-30
223	Cawood	Selby	York	N.E.	20	1	9-9-30
224	Swanton Morley	Dereham	Norwich	E.	9	1	12-9-30
225	Rawcliffe	Goole	Lincoln	N.E.	15	1	16-9-30
226	Drayton	Abingdon	Oxford	S.Mid.	9	1	16-9-30
227	Ashley	Market Drayton	Stoke-on-Trent	N. Wa.	11	1	23-9-30
228	Hallbankgate	Carlisle	Lancaster	N.W.	11	1	23-9-30
229	Dunnington	York	York	N.E.	14	1	23-9-30
230	Sandon	Stafford	Stoke-on-Trent	N. Wa.	13	2	24-9-30
231	Harwell	Abingdon	Oxford	S.M.	13	1	29-9-30
232	Sigglesthorne	Hornsea	York	N.E.	12	1	30-9-30
233	Roslin	Loanhead	Edin. Inner	Scot. E.	33	1	30-9-30
234	Ythanwells	Huntly	Aberdeen	Scot. E.	10	3	2-10-30
235	Snape	Saxmundham	Colchester	E.	11	1	6-10-30
236	Llangranog	New Quay	Swansea	S. Wa.	9	1	7-10-30
237	Hamstall Ridware	Rugeley	Stoke-on-Trent	N. Wa.	11	1	7-10-30
238	Hemingboro	Selby	York	N.E.	12	1	7-10-30
239	Nesscliffe	Shrewsbury	Shrewsbury	N. Wa.	13	1	7-10-30
240	Humberstone	Grimsby	Lincoln	N.E.	45	3	8-10-30
241	Samlesbury	Preston	Preston	N.W.	9	1	14-10-30
242	Durisdeer	Thornhill	Glasgow N.	Scot. W.	9	1	14-10-30
243	Shaugh Prior	Plymouth	Plymouth	S.W.	16	1	16-10-30
244	Arreton	Newport	Southampton	S.Mid.	23	2	21-10-30
245	Langtoft	Duffield	York	N.E.	11	1	21-10-30
246	Culgaith	Penrith	Lancaster	N.W.	12	1	21-10-30
247	Gt. Witchingham	Norwich	Norwich	E.	17	1	27-10-30
248	St. Mabyn	Bodmin	Plymouth	S.W.	9	1	28-10-30
249	Burton Pidsea	Holl Toll	York	N.E.	9	1	28-10-30
250	Tetford	Horncastle	Lincoln	N.E.	7	1	28-10-30
251	Selbourne	Alton	Guildford	S.Mid.	16	1	28-10-30
252	Seaforde	Downpatrick	Belfast	N. Ire.	9	1	
253	Hemswell	Gainsborough	Lincoln	N.E	13	1	29-10-30
254	Tarland	Aboyne	Aberdeen	Sc. E.	21	2	30-10-30
255	Sutton Courtenay	Abingdon	Oxford	S. Mid.	19	2	30-10-30
256	Earl Soham	Framlingham	Colchester	E.	22	2	3-11-30
257	Uplawmoor	Glasgow Central	Glasgow City	Sc. W.	36	2	4-11-30
258	Gobowen	Oswestry	Shrewsbury	N. Wa.	14	1	4-11-30
259	Stoke Ferry	Downham Market	Cambridge	E.	18	1	4-11-30
260	Frampton Mansell	Stroud	Gloucester	S. Wa.	16	2	4-11-30

No.	Exchange.	Parent Exchange.	Engineering Section.	District.	No. of Working units initially.	No. of Units filled.	Date opened.
261	Crantock	Newquay	Plymouth	S.W.	9	2	4-11-30
262	Culloden Moor	Inverness	Inverness	Scot. E.	10	1	5-11-30
263	Walsham-le-Willows	Bury St. Edmunds	Cambridge	E.	10	1	5-11-30
264	Tredunnock	Caerleon	Newport	S. Wa.	9	1	6-11-30
265	Upper Largo	Leven	Dundee	Sc. E.	29	2	6-11-30
266	Kirkgunzeon	Dumfries	Glasgow S.	Sc. W.	11	1	7-11-30
267	Kirton	Ipswich	Colchester	E.	10	1	10-11-30
268	Adderley	Market Drayton	Stoke-on-Trent	N. Wa.	10	1	11-11-30
269	Bishops Teignton	Teignmouth	Exeter	S.W.	23	2	12-11-30
270	Blythburgh	Southwold	Norwich	E	9	1	17-11-30
271	Bishop Wilton	Pocklington	York	N.E.	12	1	18-11-30
272	Bow	Crediton	Exeter	S.W.	13	1	18-11-30
273	Holme Hale	Swaffham	Norwich	E.	11	1	18-11-30
274	Bradley	Stafford	Stoke	N. Wa.	10	1	18-11-30
275	Llanferres	Mold	Shrewsbury	N. Wa.	13	1	18-11-30
276	Wootton	Immingham	Lincoln	N.E.	11	1	19-11-30
277	Keresley	Coventry	Coventry	N.Mid.	24	2	20-11-30
278	Old Rayne	Insch	Aberdeen	Sc. E.	8	1	25-11-30
279	Loppington	Wem	Shrewsbury	N. Wa.	9	1	25-11-30
280	Drybridge	Irvine	Glasgow N.	Scot. W.	11	1	25-11-30
281	Dervock	Ballymoney	Belfast	N. Ire.	12	1	26-11-30
				Total	3865	324	

CHILDHOOD OF AUTOMATIC TELEPHONY.

FERDINAND M. STEGMANN,

Ministerial Counsellor of the Bavarian P.O. Administration, chief pioneer of Automatic Telephony in Europe.

OUR attention has been directed to an article in a supplement to a recent issue of the "Münchner Neuesten Nachrichten," by Ministerialrat Stegmann. Mr. Stegmann is very well known in European telephone circles as a brilliant engineer, possessing to an unusual degree the courage of his opinions, and as one of the pioneers of Automatic Telephony, the development of which in Europe owes a very great deal to his energy and courage. His description of the early days of automatic telephony, written in a delightfully humorous and interesting manner, cannot fail to be of interest to those of our readers who have followed developments in this particular branch of telephony.

Mr. Stegmann recalls that at the beginning of November, 1898, he was instructed by his Administration to proceed to London, in order to study the automatic switches which were being exhibited there. He says that, at this particular time, the Bavarian Administration was extremely interested in this matter. (The *fons et origo* of this interest are not difficult to guess!) This Administration is admitted to have been at that time one of the most progressive in Europe. As far back as 5th October, 1895, a switchboard had been installed at the Head Post Office in Munich for 6,000 subscribers, equipped with self-restoring indicators. This equipment, according to Mr. Stegmann, together with that installed at Zürich about the same time, but afterwards destroyed by fire, was the first of its kind in

Europe. On 29-30 July, 1899, a second Exchange was opened in Munich, equipped for 10,800 subscribers, with lamp signalling—the first time such an equipment was installed in Europe. Thanks to the excellence of this technical equipment and to a specially chosen and splendidly-trained staff, the telephone service in Munich was regarded at the end of the century, wihout exaggeration, " as a pattern to the whole world." " In spite of this," says Mr. Stegmann, " people cropped up who said that the whole complicated system of telephone traffic could be carried out solely by means of machines! This idea, at that time, was just as fantastic as is to-day the proposal to travel to the moon by means of a rocket."

After recounting the circumstances of his arrival in London on 17th November, 1898, during a thick yellow fog, Mr. Stegmann goes on to describe very amusingly his adventures in trying to find his way about the Metropolis in the dark. On the following morning, the German deputation succeeded in reaching Winchester House, 66 Old Broad Street. In a room at this address, they saw, with wonder, for the first time, the uncanny machines. The party was received by representatives of the Direct Telephone Exchange Syndicate, Messrs. Benno Seimert, Charles Hof, Consul-General Leubold and a young American Engineer called Dickinson, who demonstrated the apparatus. The principles of the so-called Strowger system were explained. Installations for 100, 200, 400, 1,000 and 10,000 subscribers were shown. Connections were established with extraordinary speed and precision. "In spite of the many defects which the system naturally possessed at that stage, it created a great impression in the minds of the visitors. Mr. Stegmann felt instinctively that this was the system of the future. After a few days of intensive study, they met three gentlemen belonging to the Automatic Telephone Exchange Company of Washington, who owned the Strowger patents. The trio appeared daily for a few hours, smoking their pipes, never uttering a word, and taking not the slightest notice of the visitors. Shortly before Mr. Stegmann and his companions left, they asked Dickinson whether they might take a switch with them to Munich. Dickinson answered that he could only agree to this with the permission of the Attorney (one of the three). The Attorney at first refused. It appeared that, shortly before, another gentleman (Dr. Feyerabend, now Secretary of State for the German Post Office) had taken away a switch to Germany, and the Attorney apparently was afraid that, if he did not take care, the whole equipment might gradually be transferred to the Fatherland! " Where do you come from? " asked the lawyer. " From Bavaria," replied Mr. Stegmann. " Bavaria; where is that? " Apparently he had never heard of Bavaria, and, in order to allay his fears, Mr. Stegmann, through Dickinson, told a little fib (only a little one!); he said that Bavaria belonged to Switzerland. The Attorney was then quite satisfied, and said " All right; you can take the switch " (which is carefully preserved in Munich as a memento of the occasion).

On his return to Munich, Mr. Stegmann reported fully on the results of his visit to London, and gave a lecture on 22nd March, 1899, to the Electrotechnischer Verein of Munich on " Automatic Telephone Exchanges." Even at that time he expressed his conviction that automatic exchanges, equipped for subscribers up to 1,000 could work satisfactorily and possessed great economic advantages over manual exchanges as regards both installation and operation. Shortly after this lecture, a young student called Friederich Merk came to see Mr. Stegmann at his house. The idea of telephone traffic carried out by automatic means had made such a deep impression on Merk that he decided forthwith to devote himself to this new aspect of engineering. He stated that during a sleepless night, he had worked out a plan whereby any subscriber in Berlin could be connected automatically with any subscriber in Paris, Rome, Petersburg, etc. Mr. Stegmann replied, " Steady! my dear Merk; we have a long way to go before reaching that stage." (Friederich Merk afterwards took a leading part as inventor and constructor in the development of automatic telephony in Europe, and was associated with all the leading firms, such as Loewe, Siemens & Halske, Mix & Genest, finally founding a company of his own).

Up to the year 1900, about 40 automatic telephone exchanges were in operation in the United States of America. The largest of these was in Augusta, Georgia, and was equipped for

600 subscribers. All these exchanges were in the hands of independent companies, *i.e.*, they had nothing to do with the huge and influential American Telephone & Telegraph Company, which decisively refused to have anything to do with the automatic system. Mr. Stegmann quotes an opinion given by one of the principal engineers of the latter company, dated October, 1898. This engineer stated—" The apparatus is generally regarded as interesting and ingenious, but entirely impracticable under working conditions." It appears that the development and dissemination of the system was considerably retarded owing to questionable financial deals by these independent companies. In Europe, the development of the automatic system, since its first demonstration in London, was followed by various Administrations with interest. The German Post Office in Berlin installed an experimental equipment for 400 subscribers in 1900, and, two years later, another for 1,500 subscribers. In Vienna, an experimental plant for 200 subscribers was put into service in the year 1904, but up to that time no automatic exchange existed for public service.

In America, at the beginning of the twentieth century, a fresh impetus was given to automatic telephony. The Strowger Company in Chicago had bought the Strowger patents and the manufacture of the apparatus was entrusted to the Automatic Electric Company of Chicago. Contradictory reports as to the success of the system reached Europe. Some of these stated that large automatic exchanges existed in Chicago, Los Angeles, Baltimore, Philadelphia and other towns. The opponents of the system contended that this was all " American humbug." For example, the most fantastic rumours were being promulgated with respect to the Chicago installation. According to these, there was a large automatic exchange for 100,000 subscribers and a widely-developed underground cable system was being constructed. In order to ascertain the real situation, Mr. Stegmann obtained leave to visit America, and went there in September, 1904. On the night of 17-18 October, on reaching Chicago from St. Louis by the " St. Louis Limited," a compatriot met him at the station and smilingly asked him whether he had not been robbed. It appeared that the same train, a few nights before, had been stopped in the open country and " total ausgeplündert." It was, of course, particularly interesting to Mr. Stegmann to make the personal acquaintance of the Chiefs of the Automatic Electric Company, which was then the chief agency for the development of the invention. He met the Engineer-in-Chief, Alexander Keith, and the two brothers Charles and John Erickson, one of whom, apparently, was regarded as a mechanical and the other as an electrical genius. Both brothers were originally farmers and had never seen a telephone exchange when they undertook their work in connection with the automatic machines. The alleged large automatic exchange in Chicago was found to be in actual existence and was working with an efficiency beyond all expectation. About 8,000 subscribers' lines were in operation. The cables for connecting the subscribers with the exchange were laid in tunnels about three metres broad and 2.3 metres high. These had been constructed with extraordinary speed by the Illinois Telephone Construction Company. They had not, however, been made for this particular purpose, but for the underground transport of goods from railway stations to business houses. In order to obtain a reliable opinion of the quality of the automatic service, Mr. Stegmann went into restaurants, shops, etc., and selected and spoke to various subscribers. The connections were made and severed with astonishing rapidity and reliability. He heard nothing but praise for the new system in every quarter. One day, when he asked a subscriber, " Have you really no difficulties? " he was informed—" Oh! yes, we have had difficulties, but only when the user had such a thick finger that he could not insert it in the holes of the dial! "

On his return home, Mr. Stegmann had a long conversation with the Chief Engineer of the New York Telephone Company—Mr. John Carty (now General Carty) who afterwards, as the Engineer-in-Chief and technical leader of the American Telephone & Telegraph Company, became so famous. In reply to the statements made by Mr. Stegmann, in which the latter indicated the tremendous impression which the automatic telephone had made upon him and stated his firm conviction that the general introduction of this system was only a question of time, Mr. Carty adopted a very non-committal

attitude. Indeed, on the occasion of the second international meeting of Telegraph Engineers of State Administrations in Paris in the year 1910, Mr. Carty still refused to bless the full automatic system.

In his report to the Bavarian Minister of Communications, Mr. Stegmann stated—"To sum up, I should like to express my conviction that the substitution of the Strowger system or possibly another equally efficient system in place of manual exchanges is only a question of time. In this connection, I am still of the opinion, expressed in 1898, according to which an automatic system is the most suitable for very large installations."

This report merely caused head-shaking on the part of the authorities of the Administration. In spite of this scepticism, the report was the basis of a decision some years later to instal automatic working in Munich.

After the first demonstration of the Strowger system in London, Messrs. Ludwig Loewe & Co., of Berlin, obtained the patents for all European countries, except England and France, and entrusted the manufacture of the machines to the German Arms and Munition Factory in Carlsruhe. The telephone industry, however, for the time being, was antagonistic. Even far-seeing men, such as the Director of the Wernerwerke of Siemens & Halske, the unforgettable Professor Dr. Raps, expressed their scepticism in no uncertain manner. As often as he met Dr. Raps, whether in Berlin, Munich or Vienna, Mr. Stegmann never lost an opportunity of endeavouring to persuade him to undertake the introduction of automatic telephony. It was not until the year 1907, however, that a "Company for Automatic Telephony" was formed under the auspices of Siemens & Halske. This company took over the patents and manufacturing rights from the Loewe Company. The new company was afterwards incorporated in Siemens & Halske, which firm is now energetically perfecting the automatic system and adapting it to German conditions.

The first full automatic exchange for the public service in Germany was opened at Hildesheim on 10th July, 1908, and was equipped for 900 subscribers. The effective development of automatics in Germany, as in other countries on the Continent of Europe, began only when the Bavarian Ministry of Communications, under the direction of Herr von Frauendorfer, at the beginning of 1908, decided to convert to automatic working the whole of the local telephone system of Munich, with the installation of exchanges for 100,000 subscribers. "It must be confessed," says Mr. Stegmann, "that this decision was not taken without difficulty, and required a very high degree of courage in accepting responsibility." When the head of the technical department concerned, the jovial Ministerial-Director von Bredauer, affixed his signature, with a heavy heart, to the contract with Siemens & Halske, he laid his pen down with the words "That's that: either it goes, in which case all's well, or it does not go, and then I go!"

The first provincial exchange with preselectors, junction lines to other exchanges and central battery working, having a capacity of 5,000 lines, was opened on 4th November, 1909, in the Schwabing area. At first it was not satisfactory. A storm of indignation raged for months in the daily press. Indeed, this movement of antagonism went so far that a committee of dissatisfied subscribers, who had been accustomed to the excellent manual working, and composed also of some deputies of the Bavarian Landtag, insisted on the abolition of the automatic equipment. It was only slowly and gradually that the storm subsided. The members of the public, who originally were themselves responsible for difficulties, owing to false manipulation, and had of course to become accustomed to the new system of telephony, soon found the advantages of the automatic system and became enthusiastic supporters. The extension of automatic working was energetically pursued until the outbreak of war. During the second year of the war, *i.e.*, on 1st April, 1915, a further exchange at Neuhausen was installed, but, after this, a long interval occurred before further extensions took place. Mr. Stegmann gives details of the opening of exchanges in 1922 and 1923, in which latter year the whole of the Munich-Pasing local system was converted to automatic working. In this system, which extends to the suburbs, there are now working eight full automatic exchanges and 13 semi-automatic exchanges, with about 43,500 lines and 77,000 subscribers' stations.

Mr. Stegmann claims that Munich must be

famed for all time for being the first large city on the European Continent to be equipped with full automatic telephone exchanges. It was in Munich that the first proof was given that large automatic telephone exchanges are superior to manual exchanges from operating, technical and economic points of view.

In America, up to May, 1907, the Automatic Electric Company had built 73 automatic exchanges of various sizes, all for the so-called "independent companies." In the home of automatic telephony, progress was hindered because of the fact that the mighty Bell concern, strangely enough, firmly maintained its antagonistic attitude. It was only after the war, *i.e.*, from the year 1921, that the American Telephone & Telegraph Company began to instal the automatic (dial) system in the large towns. The Strowger (step-by-step) system is employed in places with only one exchange and in towns of medium size, where there are several exchanges.

At the beginning of 1930, there were in operation 194 such Exchanges, with 1.6 million lines. For the larger cities, such as New York, Chicago, San Francisco, etc., a system of the Western Electric Company called the "Panel System" has been developed. At the beginning of 1930, 128 Exchanges, also with 1.6 million lines, equipped according to this very complicated system, were in service.

Mr. Stegmann visited America (Chicago) again in the autumn of 1926 and found that in the meantime, the Automatic Electric Company had expanded enormously. (This Company supplies at the present time the Strowger apparatus for the Bell Companies). Strowger, Dickinson and Keith were all dead. Only the two Ericksons remained. They were found to be still employed with the Automatic Electric Company, but occupied very subordinate positions—"inventors' fate!"

Mr. Stegmann concludes his very interesting article as follows:—

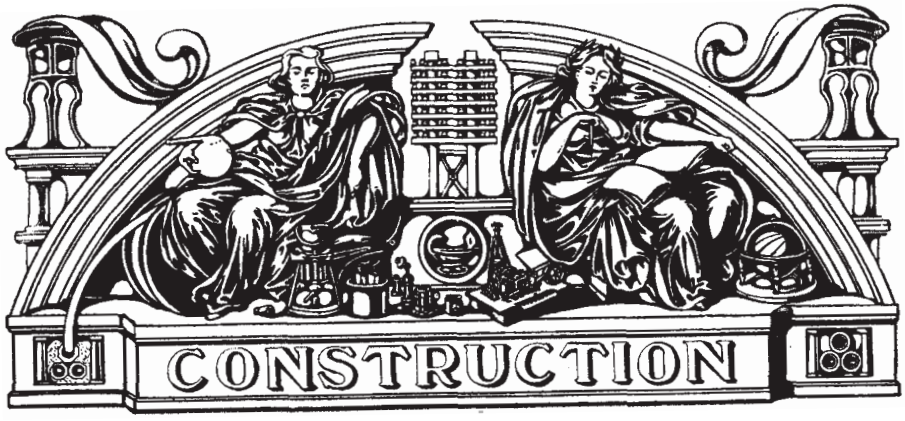
"In large cities, manual exchanges are things of the past. Wherever, in such communities, manual exchanges have to be replaced or additional exchanges installed, the automatic system will hold the field. This system, however, is being more and more developed in smaller towns and villages and, in the not distant future, whole countries will be converted to automatic working.

"Even in the extension of automatic telephones to country places, Bavaria has been a pioneer." (Mr. Stegmann gives details of the development since 1922 in this respect, and states that, already in Bavaria, serious consideration is being given to the inauguration and development of long-distance automatic traffic).

"No one finds it astonishing to-day that he is able, by his own efforts, to establish and sever telephone connections with other subscribers. Neither, however, do people consider what a tremendous effort of intelligence, pertinacity and courage in accepting responsibility was necessary in order to perfect this engineering marvel. It is perhaps not out of place to remind the younger generation that there were other times in which the transmission of human speech was by no means so perfect as it is to-day.

"The development of telephony during the last 30 years borders on the fabulous. The fact that all the 30 million telephone stations throughout the world can, by means of the transatlantic services, establish satisfactory communication with one another at any time, and that from any telephone station it is now possible to communicate with large passenger steamers on the ocean or with aircraft flying over foreign continents, might give reason for the belief that there is nothing more to be done or to be invented. It will probably be found, however, if the signs of the times are not misleading, that the development during the next 30 years as regards the number of telephone stations and the ease and speed with which these can be connected together, will be such that the achievements of the past will be completely eclipsed. Everything is becoming faster and faster. Whether, however, people will be happier by reason of this than they were in the good old times of mail coaches is another question."

B.J.S.



THE ANGLO-BELGIAN (1930) SUB-MARINE TELEPHONE CABLE.

M. E. Tufnail and J. F. Doust.

SYNOPSIS.—This article describes the construction and briefly the laying operations of the Anglo-Belgian (1930) Submarine Telephone Cable. The Transmission characteristics of the pair, phantom and super-phantom circuits of the completed cable from Canterbury to La Panne are given.

Another telephone link between England and the Continent was completed when the last joint in the Anglo-Belgian (1930) Cable was made at Dumpton Gap on 7th September, 1930. This cable is the sixth paper-core submarine telephone cable and provides twenty-four channels of communications for Anglo-European international telephony. The total number of speech channels now available in such cables is 120, a large increase since the first paper-core cable was laid, viz., the Anglo-Dutch (1924), which provided 12 circuits.

The Anglo-Belgian (1930) Cable was manufactured by Messrs. Siemens Bros. & Co., Ltd., Woolwich, London, who were responsible for the laying of the cable between Canterbury Repeater Station (England) and La Panne Repeater Station (Belgium).

The cable consists of approximately 16 nautical miles of land cable between Canterbury and Dumpton Gap and 50½ nautical miles of submarine cable from Dumpton Gap to La Panne. The land and submarine cables are identical in electrical characteristics, but the land cable is not armoured and has only one lead alloy sheath. The cable contains 28 conductors of solid copper, .08 inch in diameter; each conductor is closely wound with one layer of iron wire, .008 inch in diameter, which increases the inductance of the pair circuits to approximately 12½ milli-henries per nautical mile.

Each conductor is insulated with four helical wrappings of paper, the outer paper being coloured for identification purposes. The insulated conductors are arranged in seven quads, formed by stranding four insulated conductors on a paper centre in the colour order: Red, Blue, White with a black line, and White. The diagonally opposite wires, *i.e.*, Red and White-black, Blue and White form the pair circuits. Each quad is lapped with a coloured paper tape which provides identification. The cable is formed by stranding seven quads, the colour order being: centre, Green; outer layer Red_1, $Blue_1$, $White_1$, Red_2, $Blue_2$, and $White_2$. The interstices are filled with packed paper wormings to provide a compact cable, two worming papers being coloured orange to distinguish the Red_1 quad.

The protection of the cable consists of two continuous, seamless sheaths of a Lead-Antimony-Cadmium Alloy (Pb 99.25%, Cd .25%, Sb. .5%) which are served with jute to form a

bedding for twenty-five No. 4 S.W.G. and three No. 12 S.W.G. stranded armouring wires. The finished cable weighs 26½ tons per nautical mile and is 2.58 inches in diameter. A cross-section of the cable is shown in Fig. 1.

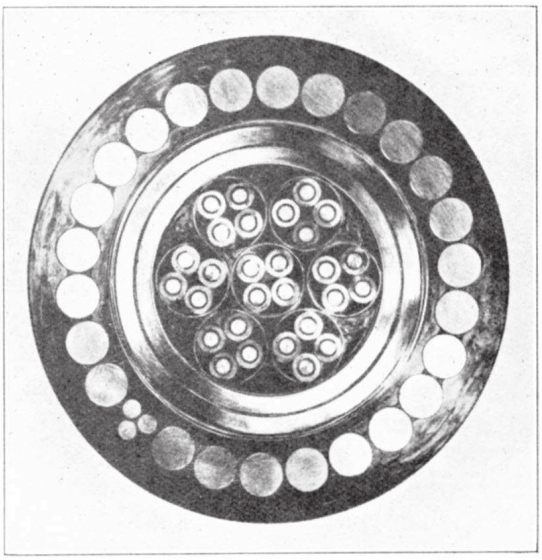


Fig. 1.—Cross-Section, Anglo-Belgian Cable (1930). Overall approx. 2.6″.

It will be seen that, mechanically, the cable only differs from the 1926 cable in respect of the alloy sheathing, the latter providing greater mechanical protection than pure lead. A different method of jointing the land cable has, however, been employed to ensure that the quads retain their relative positions throughout as in the sea cable. This restricted method of jointing the quads was necessary for the satisfactory working of circuits which are superimposed on the phantom circuits of the six outer quads, See Fig. 2. One such circuit is formed on two diagonally opposite quads, such as Red$_1$ or Red$_2$ (called the " A " circuit); a second is formed on the two remaining pairs of quads, one pair of adjacent quads forming each element of the circuit (called the " B " circuit; the third super-phantom (called the " C " circuit) is superimposed on these two circuits. It will be seen that the " C " circuit is not symmetrical in regard to its two elements and this prevents the further super-position of an earth super-phantom circuit.

There are three ways of choosing the " A " super-phantom circuit (*i.e.*, using the Red, Blue or White quads), and the choice of this circuit necessarily decides the formation of the " B " and " C " circuits. Any " B " or " C " circuit will be described herein by the colour of the quads forming the associated " A " circuit. Thus, White " C " will be the circuit formed with quads White$_1$ and White$_2$ as the corresponding " A " circuit.

It is possible to super-impose circuits on the phantoms in other ways, but these will not permit the working of more than two circuits owing to capacity unbalance considerations.

With regard to the side circuits of the cable, in addition to the usual requirements of cross-talk and attenuation limitations, details of which are given later, the circuits were required to have the same characteristic impedance, at frequencies from 300 to 2000 p.p.s., as the circuits in the 1926 cable. This feature provides for the easy interchange of terminal apparatus and also reduces the stock of spare cable held in readiness for repair purposes. The limit guaranteed by the manufacturers for this impedance agreement

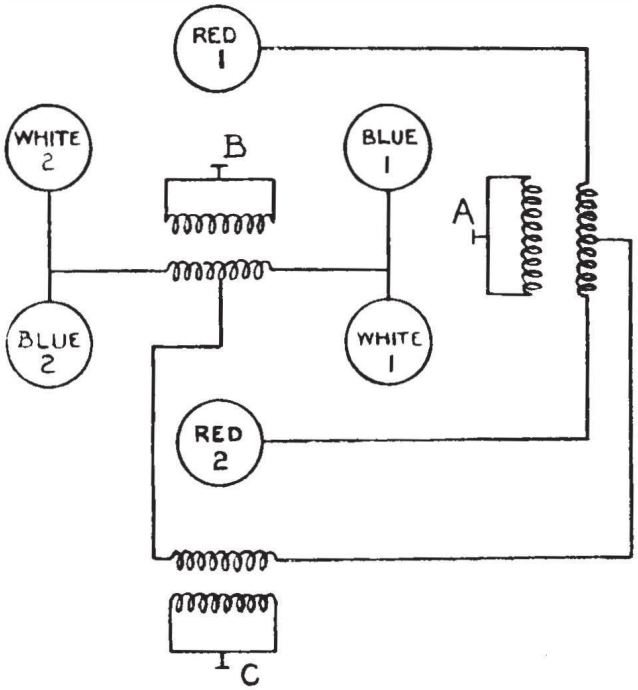


Fig. 2.—Method of forming A, B and C Super-phantom Circuits.

was ± 7½% between the mean of the characteristics of all side circuits in each cable and this guarantee has been met.

The laying of the land cable followed the usual lines, the balanced sections, approximately four nautical miles in length, were joined with selected joints to form the total of 16 nautical miles of cable from Canterbury to the coast. Tests on this 16 nautical miles showed that it complied with the requirements for the completed cable.

The submarine cable was laid in two portions, one of 16 nautical miles from La Panne on August 26th and one of 34 nautical miles from Dumpton Gap on September 2nd. Fig. 3

FIG. 3.—" KATHERINE " READY TO LAND SHORE END AT DUMPTON GAP.

shows the drifter " Katherine " laying the shore end at Dumpton Gap. A sea joint between the two lengths was then made on board the cable ship " Faraday." This joint was selected for reduction of near and distant end cross-talk by switching tests.

After the completion of the preliminary tests on the submarine cable, which showed the laying to have been satisfactorily completed without damage to the cable, the final joint was made at Dumpton Gap and, in this case also, near and distant end cross-talk tests were made to determine the method of connecting the wires of each quad. The length of the cable after completion was 66.52 nautical miles.

A description of the measured electrical characteristics of the circuits of the cable follows. Section I. deals with the pair and phantom circuits and Section II. with the super-phantom circuits.

SECTION I.

Direct Current Tests.

Conductor Resistance: Mean of 28 wires = 9.98 ohms per naut. Insulation Resistance, measured with 130 volts, between each quad and all other quads earthed, after one minute electrification. Maximum reading 31,000 megohms per naut. Minimum reading 26,500 megohms per naut.

Alternating Current Tests.

1. *Cross-talk.*—Table No. 1 gives the speech cross-talk between the side circuits and the phantom circuit of each quad. The figures represent the power transference ratio between the disturbed and the disturbing circuits, expressed in decibels. The maximum values guaranteed by the contractor are also given in the table.

2. *Transmission Efficiency.*—The attenuation frequency characteristics of the side and phantom circuits are given in Fig. 4, from $f = 300$ to $f = 7000$ p.p.s. These characteristics were determined by calculation from the open and closed impedances of the circuits of a ten naut.

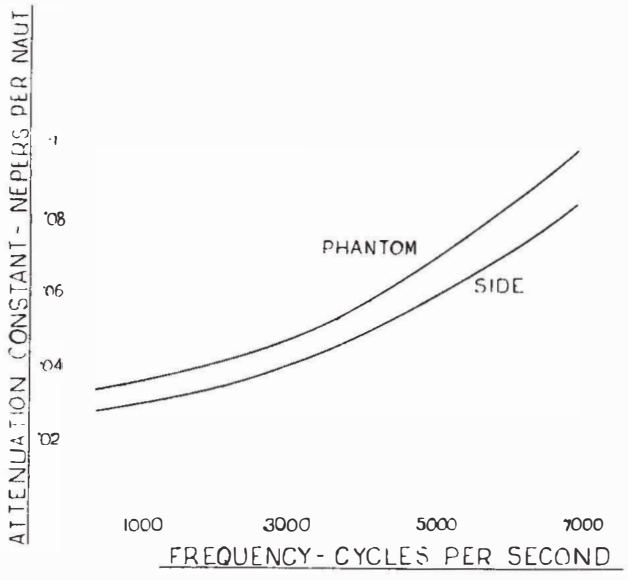


FIG. 4.—ATTENUATION FREQUENCY CHARACTERISTICS OF SIDE AND PHANTOM CIRCUITS FROM 400 TO 7,000 CYCLES PER SECOND.

length of cable. The tests at frequencies above 4000 p.p.s. were made with an A.C. Bridge by heterodyning the receiver current with a second oscillator and balancing out the beat note so produced by adjustment of the variable bridge arm. The values measured on the completed cable over the frequency range from $f = 300$ to

f = 3000 p.p.s. are in close agreement with those given in Fig. **4** and are shown in Fig. **5**, which also gives the specified maximum values for the side circuits.

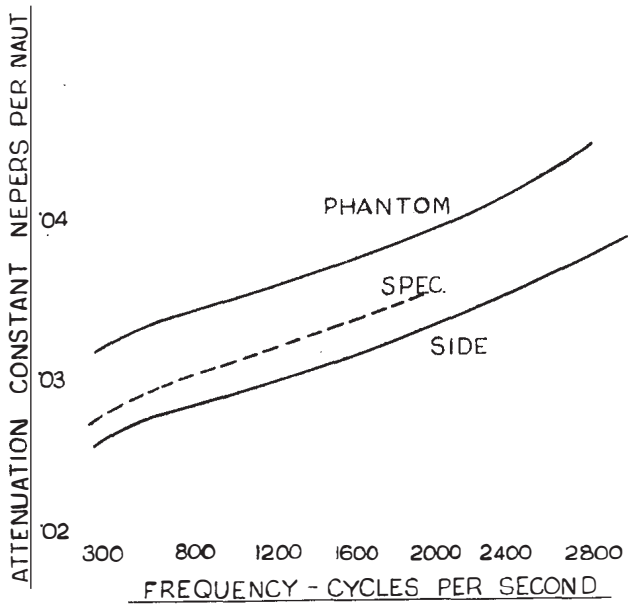


FIG. 5.—ATTENUATION FREQUENCY CHARACTERISTICS OVER AUDIO RANGE.

The amplitude distortion of the cable from f = 300 to f = 3000 p.p.s. is .86 and .93 nepers for the side and phantom circuits respectively. The wave-length constants of the side and phantom circuits were found to be directly proportional to the frequency and correspond to

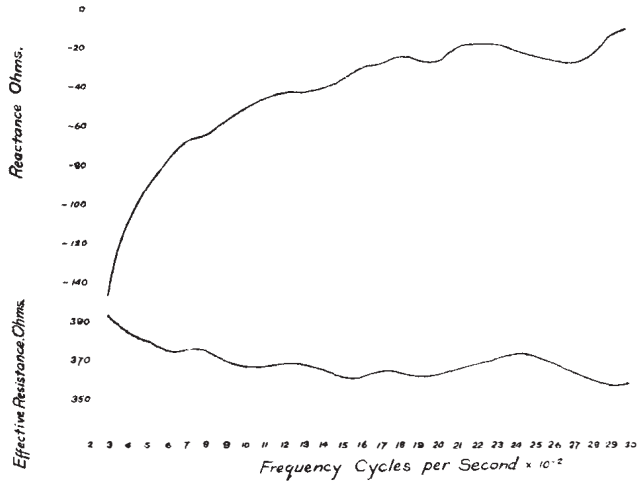


FIG. 6.—IMPEDANCE FREQUENCY CHARACTERISTICS OF SIDE CIRCUITS FROM 300 TO 3,000.

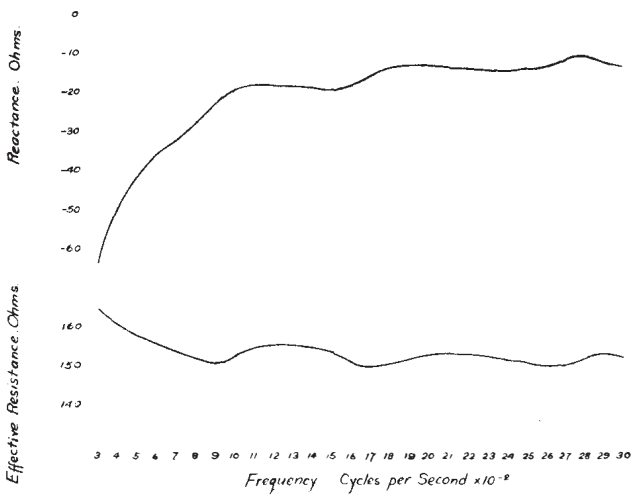


FIG. 7.—IMPEDANCE FREQUENCY CHARACTERISTICS OF PHONTOM. TESTED AT LA PANNE.

constant velocities of 30,000 and 25,000 nauts per second respectively.

Table No. 2 shows the mean primary constants of the circuits per nautical mile measured at 800 p.p.s. in the Contractors' works.

3. *Characteristic Impedance and Uniformity of Electrical Constants.*—Fig. **6** shows the variation of characteristic impedance with frequency in the case of a side circuit tested at Canterbury over the usual audio-frequency range. The curve is similar in shape to the curves of other pairs tested at Canterbury and also at La Panne. The maximum deviation of the impedance from the mean curve was found to be $3\frac{1}{2}$%, in the case of some circuits when tested at La Panne. This deviation is due to the difference of impedance between the two portions of the sea cable laid from the Belgian

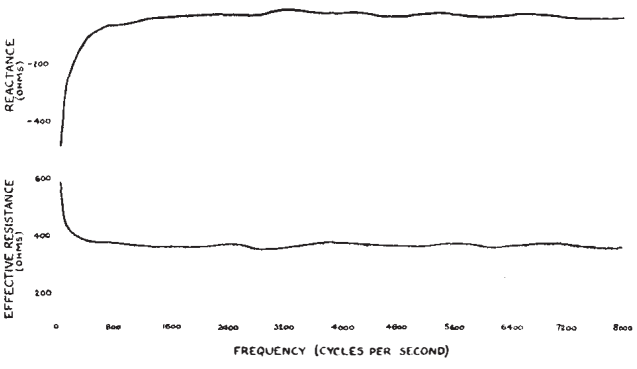


FIG. 8.—IMPEDANCE FREQUENCY CHARACTERISTICS OF SIDE CIRCUIT FROM 60 TO 8,000.

and English coasts. The figure is, however, within the guaranteed maximum of 5%.

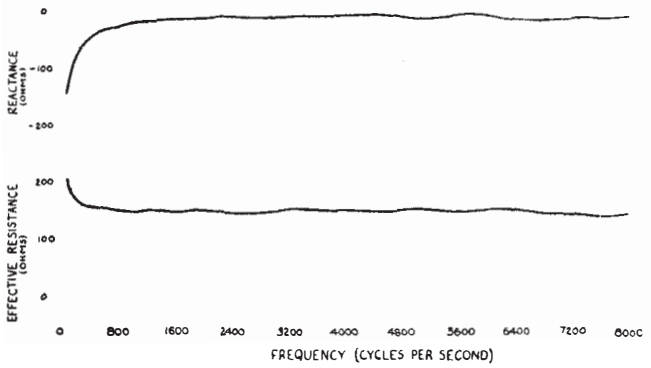


FIG. 9.—IMPEDANCE FREQUENCY CHARACTERISTICS OF PHANTOM FROM 100 TO 8,000.

Fig. **7** shows the same characteristic for a phantom circuit tested at La Panne.

The characteristic impedance variations of side and phantom circuits over a larger frequency range (from f = 60 p.p.s. to f = 8000 p.p.s.) are shown in Figs. **8** and **9** respectively. These curves indicate that from the point of view of impedance deviation little difficulty would be experienced in the operation of repeaters between these limits of frequency, and that the cable may therefore be considered satisfactory in this respect for the transmission of music.

SECTION II.

Super-phantom Circuits.—The super-phantom circuits were not included in the specification of the cable and primary consideration was therefore given during the construction of the cable to the side and phantom circuits. Tests carried out at Messrs. Siemens Bros. Works were made with the object of determining whether satisfactory super-phantom circuits could be provided without degrading the specified circuits in any respect. The tests were carried out on the completed ten-naut. armoured lengths, in order to avoid delay to the completion of the cable.

At four joints the arrangement of the quads was determined by switching tests made on the

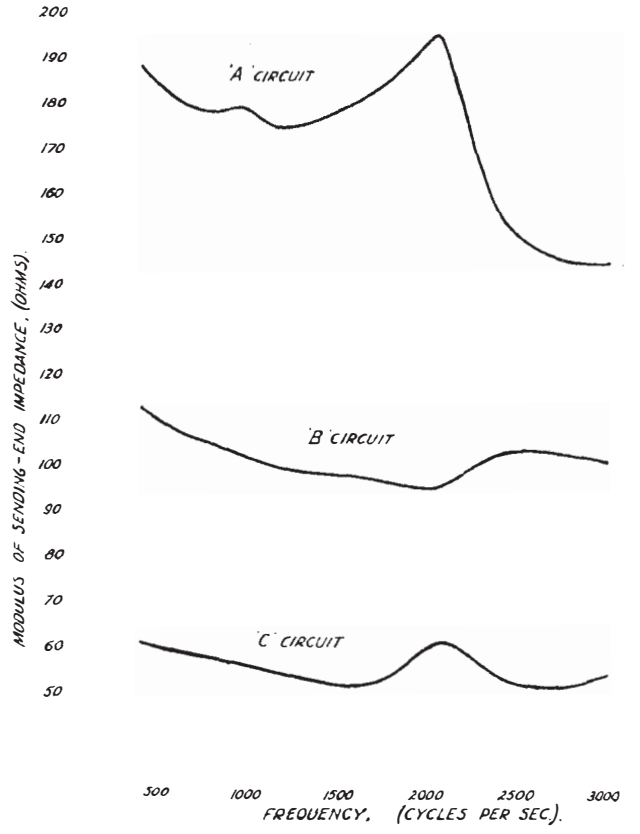


FIG. 10.—IMPEDANCE AND FREQUENCY CHARACTERISTICS OF SUPER-PHANTOMS. 10 NAUT. LENGTH.

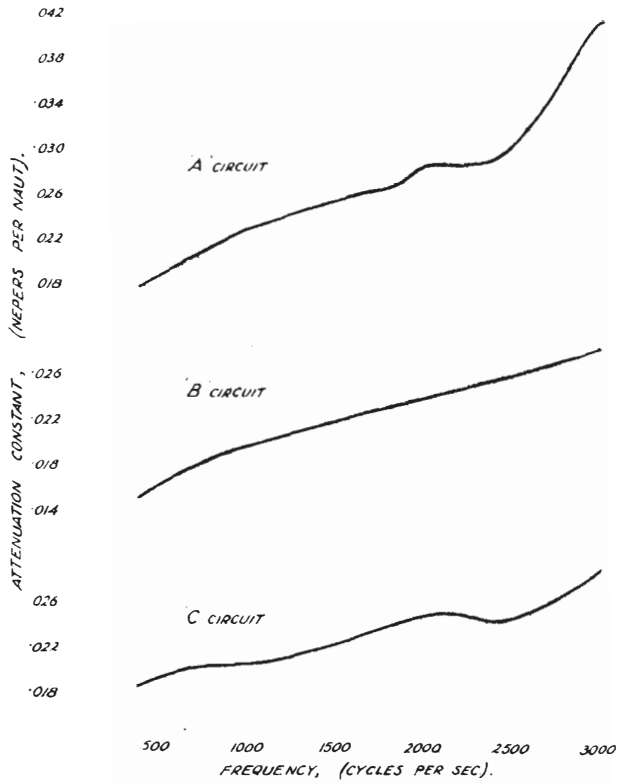


FIG. 11.—ATTENUATION CONSTANT AND FREQUENCY CHARACTERISTICS OF SUPER-PHANTOMS. 10 NAUT. LENGTHS.

super-phantoms, the two joints nearest the ends being switched for reduction of near-end cross-talk and the two joints nearer the centre being switched for reduction of distant-end cross-talk. Those joints switched for near-end cross-talk were dealt with first and the super-phantoms which would be used, if possible, were chosen at the English and Belgian ends of the cable. The joints switched for distant-end cross-talk were tested simultaneously, the middle portion (14 nauts. in length) of the cable being, in effect, rotated between the end portions (one of 20 nauts. and one of 16 nauts.) until the six possible arrangements of quads at the joints had been tested for distant-end cross-talk. Of the latter two joints, only one was made in the contractors works, the other was the joint made at sea on September 2nd. In this case the arrangement of quads giving the best super-phantom circuits was scheduled from the results of the tests in works described above, but the

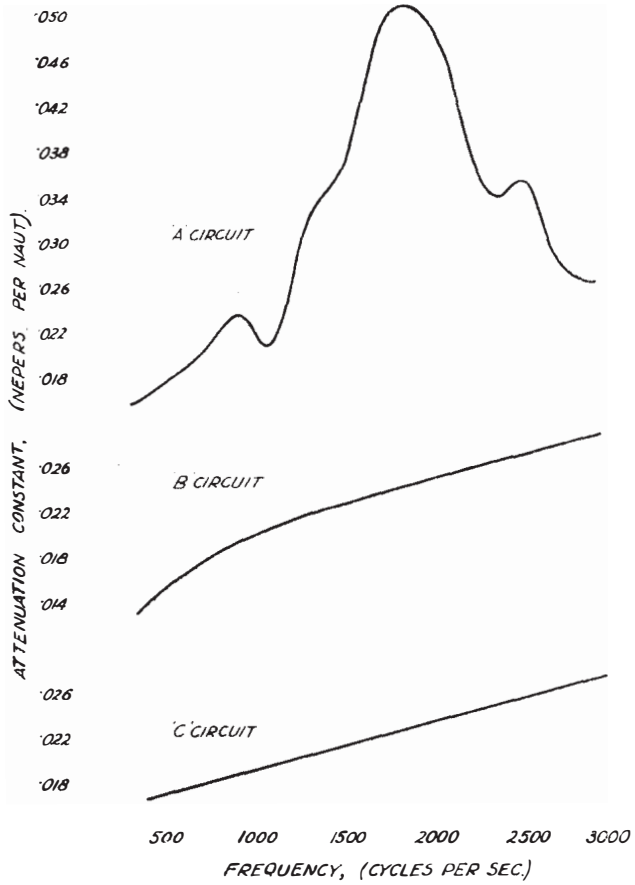


FIG. 12.—IMPEDANCE FREQUENCY CHARACTERISTICS OF SUPER-PHANTOMS. COMPLETED CABLE.

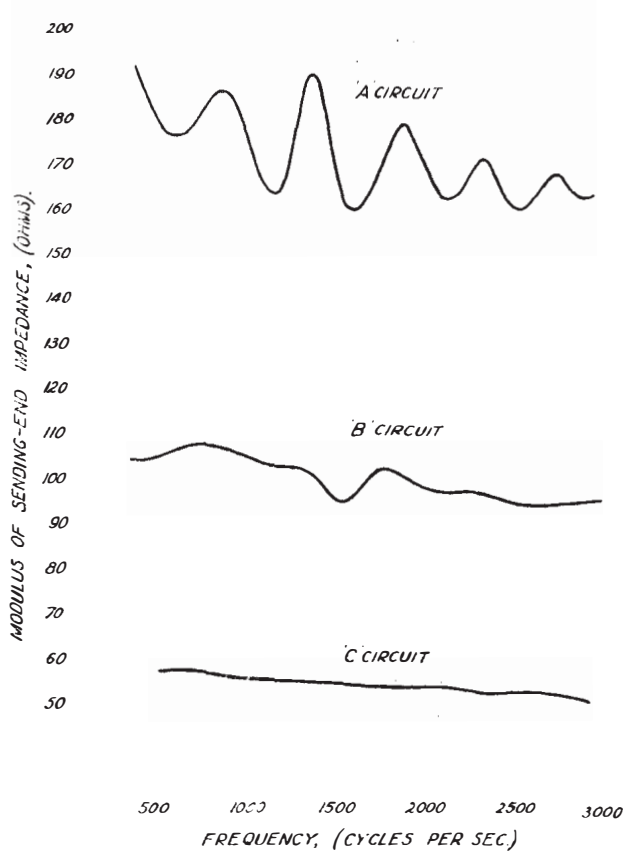


FIG. 13.—ATTENUATION FREQUENCY CHARACTERISTICS OF SUPER-PHANTOMS. COMPLETED CABLE.
Measured with Speech.

method of jointing the wires of the quads was determined by switching tests during the jointing operations.

The tests made on the super-phantom circuits were utilised to determine only the arrangements of the *quads* at the joints, the method of jointing the *wires* of the quads being decided by switching tests for reduction of cross-talk between side circuits and between side and phantom circuits. Had the cross-talk between circuits within the quads proved unsatisfactory, then, although the efficiency of the super-phantom circuits in regard to cross-talk would have been impaired, the arrangement of the quads would have been changed.

Considerable improvement of the super-phantom circuits was effected by means of the above tests, and there is little doubt that a further reduction in cross-talk could have been obtained had it been possible to make similar tests earlier in the process of manufacture of the cable.

Figs. **10** and **11** show the variation of character-

istic impedance and attenuation with frequency for the super-phantom circuits of a ten-nautarmoured length for frequencies below $f = 3000$ p.p.s. A marked irregularity occurs in the impedance curve of the A circuit. This is probably due to transference of energy (cross-talk) to other super-phantom circuits not directly in use.

Figs. **12** and **13** are similar characteristics for the completed cable over the same frequency range, calculated from open and closed impedance measurements. The impedance curve of the A circuit shows a comparatively regular variation and the amplitude distortion for the same circuit (2.56 nepers between $f = 300$ and $f = 1900$ p.p.s.) as indicated by the attenuation curve is considerable.

The difficulty of constructing an efficient balance for a two-wire repeater would render the A circuit rather unsatisfactory for normal traffic purposes, but it could be used as a service line between repeater stations. The impedance and attenuation characteristics of the B and C circuits are more regular and they could be used for commercial purposes when required.

The cross-talk results for the super-phantom circuits are given in Table No. 3. The table shows that it is possible to provide super-phantom circuits in a seven quad submarine cable.

TABLE 1.

NEAR END AND DISTANT END CROSSTALK BETWEEN SIDE CIRCUITS AND BETWEEN SIDE AND PHANTOM CIRCUITS.

Measured with Speed.

All values in decibels.

QUAD	AB/Phantom			CD/Phantom			AB/CD		
	Tested at Canterbury	Tested at La Panne		Tested at Canterbury	Tested at La Panne		Tested at Canterbury	Tested at La Panne	
	N.E.	N.E.	D.E.	N.E.	N.E.	D.E.	N.E.	N.E.	D.E.
GREEN	76	72	70	71	72	78	85	86	100
RED_1	72	68	66	74	67	70	90	86	98
$BLUE_1$	72	67	74	71	70	66	85	82	94
$WHITE_1$	74	70	68	73	70	62	84	82	90
RED_2	75	70	68	67	67	64	89	82	104
$BLUE_2$	71	67	74	72	70	66	87	82	106
$WHITE_2$	72	71	72	72	70	64	90	82	90
SPEC*n*	61			61			70		

TABLE 2.

MEAN PRIMARY CONSTANTS PER NAUTICAL MILE OF SIDE AND PHANTOM CIRCUITS AT $f = 800$ *p.p.s.*

Circuit.	R Ohms.	L Milli-henries	C Micro-farads.
Side	10.90	12.78	0.092
Phantom	5.34	6.04	0.268

TABLE 3.

NEAR-END AND DISTANT-END CROSSTALK BETWEEN SUPERPHANTOM CIRCUITS AND BETWEEN SUPERPHANTOM AND PHANTOM CIRCUITS.

Measured with Reed Hummer Supply.
All values in decibels.

Disturb.	Listen.	Cross-talk (*db*).		
		At Canterbury. Near End	At La Panne.	
			End. Near	Distant End
C	A	63	55	61
C	B	62	59	68
A	B	63	60	72
A	Red$_1$ (+)	60	57	64
A	Red$_2$ (+)	66	66	64
B	Blue$_1$ (+)	65	60	70
B	White$_1$ (+)	67	65	65
B	Blue$_2$ (+)	61	70	70
B	White$_2$ (+)	68	63	64

[*A description of the Anglo-French (1930) cable laid about the same time as the Anglo-Belgian cable will appear in the April issue.—Eds. P.O.E.E.J.*]

OUTLINE NOTES ON TELEPHONE TRANSMISSION THEORY.

W. T. PALMER, B.Sc. (Eng.), Wh. Ex., A.M.I.E.E.

SECTIONS 2, 3 AND 4.

SECTION 2.

Simple Classical Theory of Electric Wave Propagation along two Parallel Conductors.

The theoretical case of two parallel conductors is the nearest approach to the practical case of an ordinary transmission line. It is important to bear in mind that many assumptions are made in the derivation of the following transmission equations, although, generally speaking, mathematical analysis with these assumptions gives results which enable the efficiency of telephonic circuits to be predicted and improved in practice. The principal assumptions made are as follows:—

(*a*) Each conductor is geometrically the same and uniform.

(*b*) Each conductor is electrically the same and uniform.

(*c*) The voltage and current at the sending end of the line are sine functions of time and continue as sine functions at all points along the line.

N.B.—A complex speech wave may be resolved into a number of sine functions by Fourier's series, or some other method, and hence the propagation of a speech wave can be studied by first treating the case of the propagation of the constituent sine waves.

(*d*) The electrical primary constants do not change with frequency and current change.

(*e*) The electrical energy is transmitted by the surrounding medium and the conductors act as guides for the wave.

(*f*) The rate of propagation of the flux in the magnetic flux plane is negligible.

(*g*) The rate of propagation of the electrostatic strain is negligible.

(*h*) The transient effects produced by connecting and disconnecting apparatus are negligible and the steady-state phenomena only considered.

(*i*) The line is supposed to be divisible into elements each containing a series-impedance branch and a shunt-admittance branch. See Fig. **4** (*a*) and (*b*).

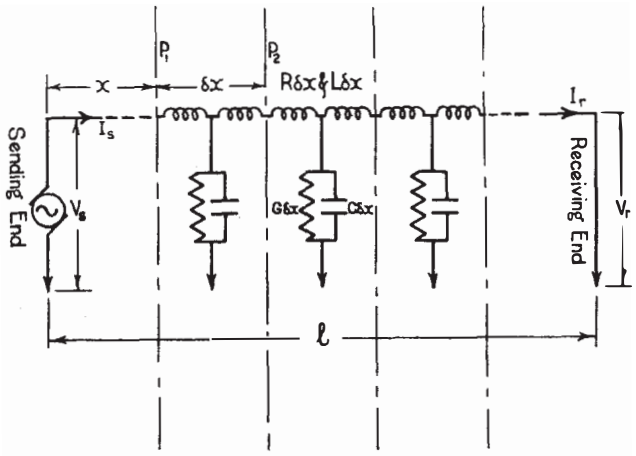


FIG. **4** (*a*).—SINGLE WIRE VALUES OF PRIMARY CONSTANTS. R, L, G AND C PER UNIT LENGTH.

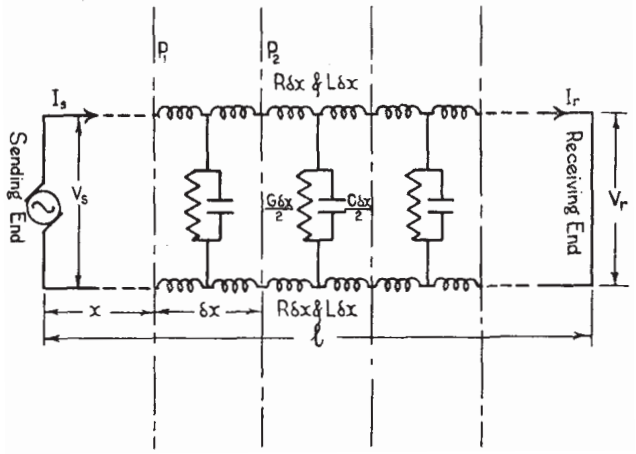


FIG. **4** (*b*).—LOOP VALUES OF PRIMARY CONSTANTS. 2R, 2L, $\frac{G}{2}$ AND $\frac{C}{2}$ PER UNIT LENGTH.

Recent developments in picture-telegraphy, voice-frequency and sub-audio telegraphy—employing conductors hitherto exclusively used for speech transmission—indicate that the assumption (*h*) cannot be neglected with impunity.

I.—*To express the Voltage and Current existing at any Point, Distant (x) from the Sending End, in Terms of the Sending End Voltage and Current respectively.*

Consider Fig. 4 and the following symbols :--

Let x denote the axis of propagation

Single Wire Values of Primary Electrical Constants.

- R = resistance of unit length of circuit in ohms
- G = leakance of unit length of circuit in mhos
- C = capacity of unit length of circuit in farads
- L = inductance of unit length of circuit in henries

I = maximum value of current at distance x from the sending end,

V = maximum value of voltage at distance x from the sending end,

v = instantaneous value of voltage and $v = V \sin \omega t$

and i = instantaneous value of current and $i = I \sin (\omega t \pm \theta)$

where ω = pulsatance of supply = $2\pi \times$ frequency

and θ = time phase angle between voltage and current at distance x from the sending end.

Hence considering the element δx and using instantaneous values of v and i :—

Let v be the voltage at the point P_1,

and $v + \delta v$ be the voltage at the point P_2,

Let i be the current in the line at P_1,

and $i + \delta i$ be the current in the line at P_2.

Then $$-\delta v = R.\delta x.i + L.\delta x.\frac{di}{dt}$$

and $$-\delta i = G.\delta x.v + C.\delta x.\frac{dv}{dt}$$

$$\therefore -\frac{dv}{dx} = R.i + L.\frac{di}{dt} \quad \text{.....(1)}$$

and $$-\frac{di}{dx} = G.v + C\frac{dv}{dt} \quad \text{.....(2)}$$

Now using maximum values for voltage and current equations (1) and (2) become—

$$-\frac{dV}{dx} = RI + j\omega LI = (R + j\omega L)I = zI \quad \text{.....(3)}$$

and $$-\frac{dI}{dx} = GV + j\omega CV = (G + j\omega C)V = yV \quad \text{.....(4)}$$

where $z = R + j\omega L$ and $y = G + j\omega C$

Differentiating with respect to x, equations (3) and (4) may be written :—

$$-\frac{d^2V}{dx^2} = z\frac{dI}{dx} \text{ and } -\frac{d^2I}{dx^2} = y\frac{dV}{dx}$$

respectively.

$$\therefore \frac{d^2V}{dx^2} = zyV = \gamma^2 V \quad \text{.....(5)}$$

and $$\frac{d^2I}{dx^2} = \gamma^2 I \quad \text{.....(6)}$$

where γ is a constant $= \sqrt{zy} = \sqrt{(R + j\omega L)(G + j\omega C)}$, is dependent for its value on the primary constants of the circuit, and is known as the *propagation constant* of the circuit. [Since γ is a complex quantity it is of the form $\beta + j\alpha$ and the real part, β, is called the attenuation constant of the circuit and the imaginary part, α, is called the wave-length constant. The reasons for these terms will be evident from the remaining considerations and from Section 3.]

Taking the differential equation (5), viz.,

$$\frac{d^2V}{dx^2} = \gamma^2 V$$

the solution is

$$V = Ae^{\gamma x} + Be^{-\gamma x} \quad \text{.....(7)}$$

where A and B are constants which can be calculated from boundary conditions. This solution can easily be verified by differentiating equation (7) twice, which will give $\gamma^2 V$, *i.e.*, equation (5).

Now differentiating (7) with respect to x and substituting in it from equation (3) we have

$$I = \frac{\gamma(Ae^{\gamma x} - Be^{-\gamma x})}{-(R + j\omega L)}$$

and since $\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$, if we write

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

we get

$$I = -\left(\frac{Ae^{\gamma x} - Be^{-\gamma x}}{Z_0}\right) \quad \text{.....(8)}$$

and Z_0, a vector quantity, dependent on the primary constants of the circuit, is called the *characteristic impedance* of the line and, as will be clearly seen from Section 3, is the sending-end impedance which would be offered by the circuit if it were extended to an infinite length.

[*Loop Values per Unit Length.*

It will be noticed that equations (7) and (8) hold for the case where loop values for the primary constants are used, because in this case:

$$\gamma = \sqrt{\left(2R + 2j\omega L\right)\left(\frac{G}{2} + \frac{j\omega C}{2}\right)}$$
$$= \sqrt{(R + j\omega L)(G + j\omega C)}$$

which is the same as for the case of single wire constants. Hence the general transmission equations derived later can be used for calculation using either single wire or loop values per unit length.]

To find Values for A and B, of equations (7) and (8), in terms of V_s, the voltage at the sending end and I_s, the current in the line at the sending end:—

Put $x = 0$ in (7) so that $V_s = A + B$

and $x = 0$ in (8) so that $I_s Z_0 = -A + B$

$$\therefore \quad A = \frac{V_s - I_s Z_0}{2}, \text{ and } B = \frac{V_s + I_s Z_0}{2}$$

Now (7) and (8) can be written—

$$V = \left(\frac{V_s + I_s Z_0}{2}\right) e^{-\gamma x} + \left(\frac{V_s - I_s Z_0}{2}\right) e^{\gamma x} \quad \ldots(9)$$

and $$I = \left(\frac{V_s}{Z_0} + I_s\right) e^{-\gamma x} - \left(\frac{V_s}{Z_0} - I_s\right) e^{\gamma x} \quad \ldots(10)$$

and these equations can be thrown into a more useful form (See Section 1, pp. (*d*)) and written:

$$V = V_s \cosh \gamma x - I_s Z_0 \sinh \gamma x \quad \ldots(11)$$

$$I = I_s \cosh \gamma x - \frac{V_s}{Z_0} \sinh \gamma x \quad \ldots(12)$$

Note 1.—These equations (11) and (12) are most important fundamental transmission equations and, though they represent maximum values of potential (V) and current (I) at a distance x from the sending end, it must be borne in mind that these quantities are *vector quantities*.

Note 2.—It will be seen from these equations that the characteristics of the circuit appear only through two parameters, viz., the propagation constant γ, and the characteristic impedance Z_0. These two quantities are in practice usually readily measurable for any given circuit and the methods of measurements, with the necessary precautions, etc., will be dealt with in a later Section.

Note 3.—The student must memorize equations (11) and (12) because numerous important relations are deduced from them. The method of derivation of these equations should be followed closely and a little study will enable the results to be obtained in a much shorter space than that just occupied.

II.—*The General Transmission Equations in Terms of the Receiving End Voltage and Current respectively.*

Let V_r = receiving-end voltage
I_r = receiving-end current
l = total length of circuit, so that
$(l - x)$ = distance of point considered from the receiving-end.

Then it can be shown, after the manner already adopted, that equations (11) and (12) become:—

$$V = V_r \cosh \gamma(l-x) + I_r Z_0 \sinh \gamma(l-x) \quad \ldots(13)$$

$$I = I_r \cosh \gamma(l-x) + \frac{V_r}{Z_0} \sinh \gamma(l-x) \quad \ldots(14)$$

III.—*To express the Attenuation Constant (β), and Wave-length Constant (α), in Terms of the Primary Electrical Constants, R, L, G and C.*

The propagation constant, γ, is a vector quantity and may be written:—

$$\beta + j\alpha = \sqrt{(R + j\omega L)(G + j\omega C)} \ldots(\text{See eqn. 6})$$

Squaring both sides we get

$$\beta^2 + 2j\beta\alpha - \alpha^2 = GR - \omega^2 LC + j(\omega LG + \omega CR)$$

Equating real and imaginary parts this gives:

$$\beta^2 - \alpha^2 = GR - \omega^2 LC \quad \ldots(15)$$

$$2\alpha\beta = \omega(LG + CR) \quad \ldots(16)$$

But since $(\beta^2 - \alpha^2)^2 = (\beta^2 + \alpha^2)^2 - (2\alpha\beta)^2$

$$\therefore \quad \beta^2 + \alpha^2 = \sqrt{(G^2 + \omega^2 C^2)(R^2 + \omega^2 L^2)} \quad \ldots(17)$$

Adding equations (15) and (17) we get

$$\text{The Attenuation Constant } \beta = \sqrt{\tfrac{1}{2}\left\{\sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)} + (GR - \omega^2 LC)\right\}} \quad (18)$$

Subtracting equations (15) and (17) we get

$$\text{The Wave-length Constant } \alpha = \sqrt{\tfrac{1}{2}\{\sqrt{(R^2+\omega^2L^2)(G^2+\omega^2C^2)} - (GR-\omega^2LC)\}} \quad (19)$$

Note.—Equations (18) and (19) are identical in form except for the sign of the last expression. They are very important equations as from them many useful simple approximations are made for dealing with problems, *e.g.*, if a circuit has negligible resistance and leakance (R = 0, G = 0) then β becomes zero and the wave-length constant becomes :—

$$\alpha = \omega\sqrt{CL}$$

In other words, when there are no resistance or dielectric losses then the wave-length constant is proportional to the frequency of supply and there is no attenuation of either voltage or current.

IV.—*Secondary Cable Constants.*

Sometimes the constants Z_0, β, α and γ are called the *secondary* cable constants. They all vary with frequency as shown in the foregoing equations, as well as being derived from the *primary* constants R, L, G and C, the latter being generally assumed to be constant with change of frequency.

Section 3.

The Imaginary Case of an Infinitely Long Circuit.

It will be shown later that what is termed "*infinite* length" conditions can be produced in an actual *finite* line and that, further, it is frequently desirable to produce "infinite length" conditions for reasons of efficiency. Hence a brief study of an imaginary infinitely long circuit is necessary.

Consider Fig. 5 below :—

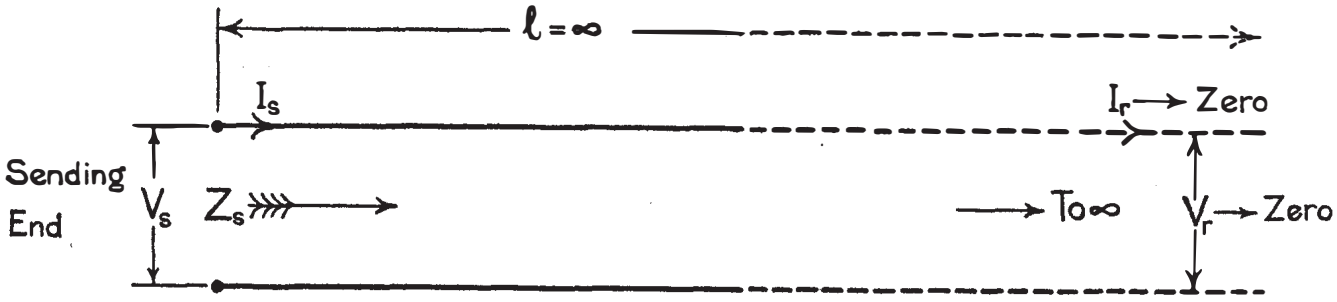


Fig. 5.—Infinitely Long Circuit.

I.—*Sending-End Impedance (Z_s).*

$\frac{V_s}{I_s} = Z_s$ = impedance measured from the sending end and looking in the direction of the feathered arrow. Since the line is infinitely long the current at the distant end (I_r) will be zero whether the end is open or closed and the voltage (V_r) will be zero also.

Equations (11) and (12) of Section 2 can therefore be each equated to zero. Using equation (11) we get :—

$$\therefore \quad V_s \cosh \gamma l - I_s Z_0 \sinh \gamma l = 0$$

$$i.e., \quad V_s = I_s Z_0 \tanh \gamma l$$

But since $l = \infty$ then $\tanh \gamma l = 1$ (See Fig. 1) and

$$\therefore \quad V_s = I_s Z_0$$

$$\text{or } \frac{V_s}{I_s} = Z_0 \quad \ldots\ldots (1)$$

Since Z_0 is a vector, let its angle be ϕ_0 (*i.e.*, write $Z_0 e^{j\phi_0}$) and then write equation (1) as

$$I_s = \frac{V_s}{Z_0} \cdot e^{-j\phi_0} \quad \ldots\ldots (2)$$

The important physical significance of equations (1) and (2) lies in the fact that the impedance $\frac{V_s}{I_s}$ *offered at its sending end, by an infinitely long line, would be equal to the characteristic impedance* (Z_0).

The same result, viz., $Z_s = Z_0$ for an infinite line, is obtained by equating equation (12) of Section 2, to zero.

II.—*Expressions for the Voltage (V) and Current (I) existing at any point distant (x) from the Sending End of an* **Infinitely Long Circuit.**

By equation (11) of Section 2 we have

$$V = V_s \cosh \gamma x - I_s Z_0 \sinh \gamma x \quad \ldots\ldots\ldots\ldots(3)$$

But in the case of an infinitely long line we have by the foregoing equation (1), $V_s = I_s Z_0$.

Equation (3) becomes

$$\therefore \quad V = V_s (\cosh \gamma x - \sinh \gamma x) = V_s e^{-\gamma x}$$

$$\therefore \quad V = V_s e^{-\gamma x} \quad \ldots\ldots\ldots\ldots(4)$$

Similarly from equation (12) of Section 2 it can be shown that

$$I = I_s e^{-\gamma x} \quad \ldots\ldots\ldots\ldots(5)$$

Substituting $\gamma = \beta + j\alpha$, then the equations (4) and (5) become, (Cf. Section 1, pp. *(c)*):—

$$V = V_s e^{-(\beta x + j\alpha x)} = V_s e^{-\beta x}(\cos \alpha x - j \sin \alpha x) \ldots(6)$$

and $$I = I_s e^{-(\beta x + j\alpha x)} = I_s e^{-\beta x}(\cos \alpha x - j \sin \alpha x) \ldots(7)$$

Equations (6) and (7) are of the same form exactly and can be represented as in Fig. **6**, which shows maximum values at different points along the line.

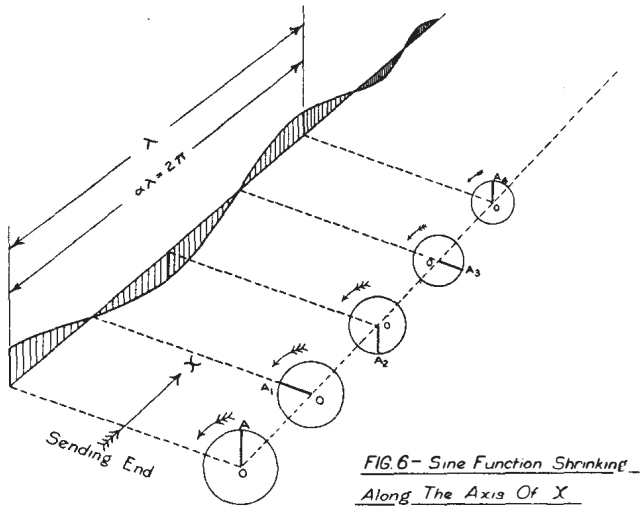


FIG. 6 – Sine Function Shrinking Along The Axis Of X

Equations (6) and (7) show that both voltage and current decrease exponentially along the line (in the infinite line condition) whilst both voltage and current lag in phase behind their respective sending-end values by an angle αl radians, or α radians per unit length. In Fig. **6** the vector OA is a shrinking sine function, *i.e.*, as it proceeds along the axis of x its magnitude decreases according to the law $e^{-\beta x}$ whilst it revolves uniformly with such a velocity as to pass through a phase angle of α radians per unit length traversed. Hence α is sometimes called the "*phase constant*" and since a complete wave or cycle is passed through by OA in 2π radians then the length of line traversed is $\frac{2\pi}{\alpha} = \lambda$ units of length, say. Hence α is often called the "*wave-length constant,*" and λ is the "*wavelength.*"

(The student should compare equations (6) and (7) with that obtained for the oscillatory discharge of a condenser which can be represented by a shrinking sine function and can be projected from a logarithmic spiral).

III.—*Velocity of Wave Propagation (v).*

If the rate of propagation of OA (Fig. **6**) along the line is α radians per mile, *i.e.*, $\frac{1}{\alpha}$ miles per radian, and if the pulsatance ($2\pi x$ frequency) of supply is ω radians per second, *i.e.*, 1 radian per $\frac{1}{\omega}$ seconds we can write $\frac{1}{\alpha}$ miles traversed per radian as:—

$\frac{1}{\alpha}$ miles traversed in $\frac{1}{\omega}$ seconds.

i.e., $\frac{\omega}{\alpha}$ miles per second.

In other words the velocity of propagation, v miles/second, is given by:—

$$v = \frac{\omega}{\alpha} = \frac{2\pi f}{\alpha}$$

SECTION 4.

The Case of D.C. Transmission—Steady State.

All the foregoing equations in Section 3 apply to D.C. transmission if the frequency, f, or pulsatance, ω, put equal to zero.

Thus for D.C. transmission over a line:—

$$Z_0 = \sqrt{\frac{R}{G}},$$

$$\gamma = \beta = \sqrt{RG}, \text{ etc.}$$

The fundamental equations (11) and (12) as well as the results derived from them also apply of course to D.C. work if ω is put equal to zero.

Examples *taken from recent Examination Papers and Solutions contained in whole or in part in Sections 1 to 4 of the Notes.*

(Some of the numerical questions will be solved in full in a later Section).

Example 1.—Explain what is meant by the propagation constant of a telephone line. If a line that may be taken as infinitely long has a propagation constant per mile of $0.04 + j\,0.08$, and the current at the sending end is 1.0 cos 5,000 t, find an expression for the current at a point 80 miles along the line. [London Univ., B.Sc., 1927.]

Note.—Use equation (5) of Section 3.

Example 2.—Discuss the part played by complex quantities in the solution of transmission problems. [City and Guilds, 1929.]

Example 3.—A line 90 miles long has the following loop-mile constants: R = 6.3 ohms; h = 0.06 henry; G = 0.15 micromhs; C = 0.054 microfarad. Find the attenuation constant and wave-length constant. [City and Guilds, 1930.]

Note 1.—Use equation (18) for β and equation (19) for α. Take ω = 5000 radians per second (mean speech value) since the value of ω was not given in the examination question.

Note 2.—Remember C must be in *farads* for calculation and G in mhos. Therefore for the equations (18 and 19), put $C = 0.054 \times 10^{-6}$ and $G = 0.15 \times 10^{-6}$.

Useful Text-books and References for Sections 2 to 4.

" The Propagation of Electric Currents in Telephone and Telegraph Conductors," by J. A. Fleming. Published by Constable, London.

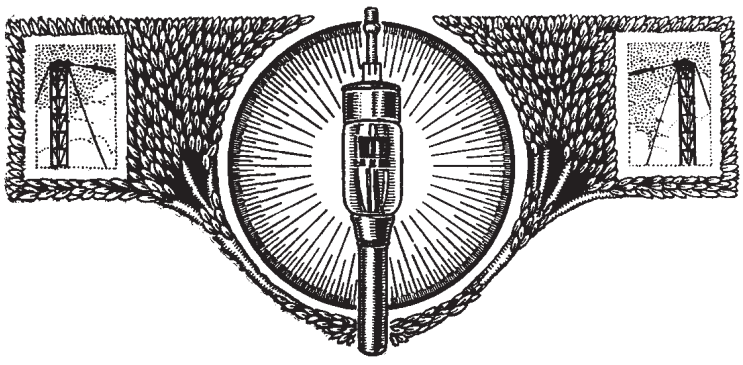
" Smithsonian Mathematical Tables—Hyperbolic Functions." Published by Smithsonian Institute, City of Washington (London Agents—W. Wesley & Son, 28, Essex Street, Strand).

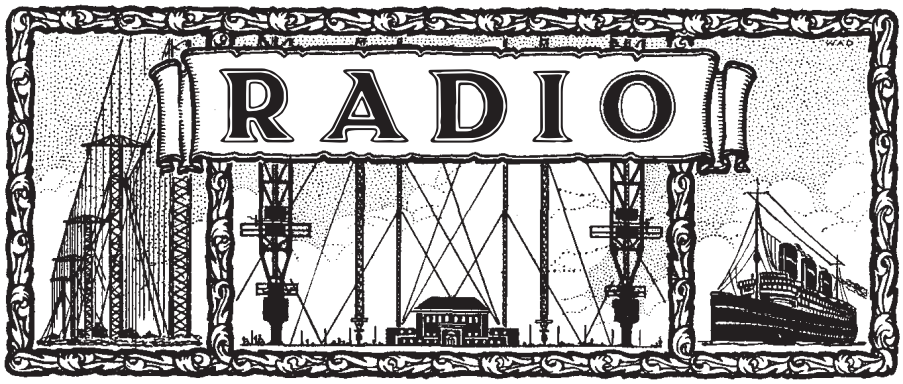
" Tables of Complex Hyperbolic and Circular Functions," by A. E. Kennelly. Published by Howard University Press.

" The Application of Hyperbolic Functions to Electrical Engineering Problems," by A. E. Kennelly. Published by Univ. of London Press.

" The Elements of Telephone Transmission," by H. H. Harrison. Published by Longmans Green & Co., Ltd.

" Telephonic Transmission," by J. G. Hill. Published by Longmans Green & Co., Ltd.





UNDERGROUND CIRCUITS FOR THE TRANSMISSION OF BROADCAST PROGRAMMES.

A. C. TIMMIS, B.Sc., A.M.I.E.E., and C. A. BEER, Wh.Sch., A.C.G.I., D.I.C.

AN essential part of the Regional Broadcasting System now being constructed in this country is the network of land lines or repeater circuits (Fig. 1) which link up the studios in London and elsewhere with the radio transmitters, so that a programme from any studio may be radiated from all or any of the transmitters. So far, aerial lines, which do not involve any Post Office repeaters, have been used almost exclusively and have proved quite satisfactory as regards transmission of the wide range of audible frequencies required for music. But, unfortunately, aerial lines are liable to breakdown and their attenuation depends to some extent on the weather. Further, noise and cross-talk may be troublesome, especially if conversation on a trunk or private line happens to be made audible by this means on thousands of loud speakers.

These are the main reasons why underground cable circuits for programme transmission are being adopted here, on the Continent of Europe and in America. It is of course well known that for all telephonic transmission in this country the overhead aerial circuits are being fairly rapidly displaced by underground cables.

From the technical standpoint the faithful transmission of music under commercial conditions will involve three main considerations :—

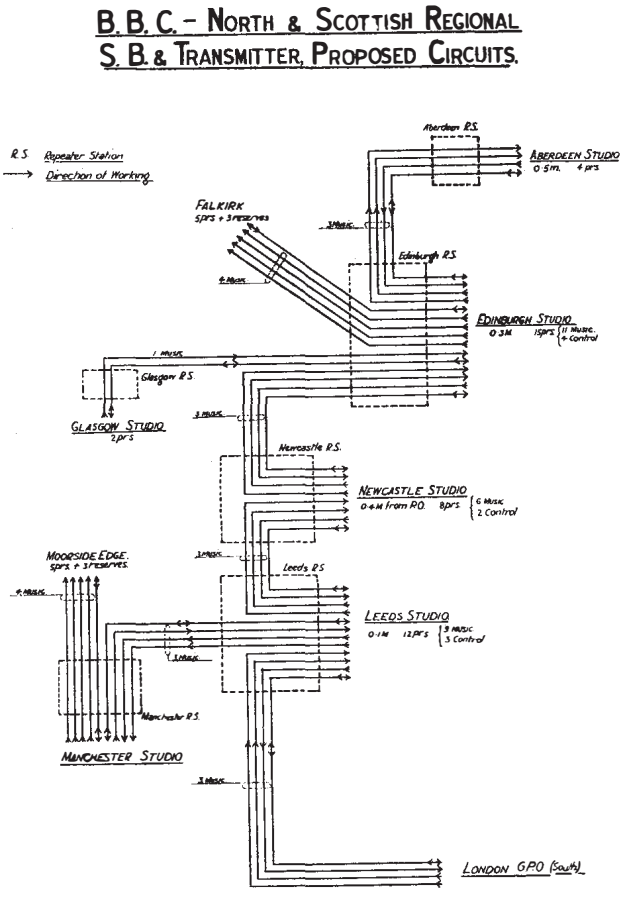


FIG. 1.

Firstly, the attenuation must be fairly constant over a wide range of frequencies and there should be no deterioration in this respect when the volume is varied over a fairly wide range. Secondly, distortion involving the production of harmonics should be negligible, and transient phenomena should similarly be indiscernible. Thirdly, cross-talk both to and from the music circuit should be negligible under all working conditions.

Frequency Range.—The B.B.C., in common with many other broadcasting concerns, has provisionally adopted a frequency range from 30 to 10,000 p.p.s. as a basis of design and there is no doubt that this range is sufficient to give complete satisfaction to listeners on the best present day loud speakers and receiving apparatus. Some administrations have shown by the use of filters introduced in the circuit that it is very rare for any musical critic to observe any difference when all frequencies above 10,000 p.p.s. are definitely cut out, while in the case of the great majority of observers the limitation of the maximum frequency to a much lower value produces no perceptible effect. It is said, however, that frequencies up to 30 kilocycles are sometimes audible, but it might be noticed that, in general, for very low and very high frequencies considerable volume must be delivered before they become audible.

As regards much narrower bands of operation, tests made on certain underground circuits, before the transmitting stations at Brookman's Park were opened, were made with the co-operation of the B.B.C. in which frequencies from 100 to 5,000 p.p.s. only were transmitted. Only 3% of the observers were able to record perceptible deterioration under normal conditions of reception, but the receiving apparatus was possibly not quite as good as the best available to-day.

More recently a test was similarly made in which a frequency range from 35 cycles to 6,500 cycles was transmitted and no difference could be detected on the best moving-coil loud speaker, except for the presence of a phenomenon probably due to transient effects when notes such as the lower range of a piano were involved. This was only detectable, however, with a quick change over.

In connection with the frequencies to be considered, it may be observed that the *fundamental* frequencies occurring in orchestral music usually have extreme minimum and maximum values of approximately 26 and 4,000 respectively, while in the case of the human voice the corresponding values are of the order of 80 and 1,000 respectively.

In view of all the considerations involved and the results obtained by independent investigators, the frequency range to be aimed at in broadcasting appears to be 35 to 8,000 p.p.s. As a contrast to this, it is interesting to note that very satisfactory commercial telephone circuits are designed on the basis of 300 to 2,400 p.p.s.

Volume Range and Measurement.—To transmit a volume range corresponding to a power ratio of one million to one, or 60 dbs, is found to be possible and the ear is generally able to appreciate the extremes. The question must, however, be also viewed from the standpoint of the residual noise unavoidable in the best systems and it is found that a volume range of 40 dbs will give great satisfaction to the listener, and can be achieved without undue expense.

Again, the volume of audio frequency signal is of importance not only when modulation of the carrier frequency at the radio transmitter is considered but also as regards the overloading of repeaters, distortion and cross-talk.

The measurement of volume therefore, which of necessity does not usually arise in telephone circuits excepting where voice-operated devices are employed, has to be given special consideration.

If the current due to speech or music is measured by means of a highly damped instrument, such as a thermo-milliammeter, the reading will indicate the R.M.S. value over a period in which the peak value of the current may change enormously. For a pure sine wave the ratio of peak to R.M.S. value is $\sqrt{2}$. In broadcast programmes this ratio may vary between 3 and 10 for speech, and even more for some kinds of music.

It is well known that valves may be overloaded by the peak value exceeding a certain amount, but the wonderfully accommodating human ear will disregard even a considerable overload if it be only momentary, of the nature of an isolated peak. If the peaks are repeated within, say, $\frac{1}{4}$ second, distortion of a very un-

pleasant kind is noticed, and the amount of this distortion probably depends on the time-integral of the peaks over a small fraction of a second.

Obviously a damped R.M.S. instrument will give very little idea of peak values, and an instrument which indicates the time-integral just mentioned is necessary. The Western Electric "volume indicator," used by the Post Office and the B.B.C., meets this requirement fairly well. It consists essentially of a rectifying valve operating a moving coil instrument whose construction is such that it may be regarded almost as a ballistic galvanometer, giving deflections proportional to the time-integral of the current over, say, 1/5 second. In use, the input to the valve is adjusted by means of a tapped transformer until the needle swings up to a certain mark which is taken as "reference volume." If average speech from a good C.B. telephone is applied, across 600 ohms, to the volume indicator the instrument should indicate reference volume.

Now, if this speech is amplified by an ordinary repeater valve whose maximum distortionless output is 57 milliwatts, then the maximum amplification which can be tolerated without sensible distortion is 10 db. That is to say, the output of the valve is 10 db above reference volume. We can therefore use the volume indicator (which is in effect a high impedance valve voltmeter) to determine the volume at any part of a circuit as a criterion of overloading, or rather, of avoidance of overloading.

If on the other hand we transmit through the same valve high quality speech from a broadcasting microphone, or music, and listen to the result on a good modern loud speaker, the distortion will be appreciable when the volume indicator shows 10 db above reference volume at the output of the valve. This is mainly because the ear cannot tolerate so much distortion (measured by the time-integral mentioned above) as in the case of commercial telephone speech, where no very high or very low frequencies are produced. Once calibrated by the judgment of a trained ear, however, the volume indicator will serve reasonably well to indicate the safe volume level at various points in a broadcasting system. At the output of a valve such as that mentioned above volumes of 4 db above reference volume for medium quality broadcast and about 5 db below, for high quality broadcasting, have been agreed upon in co-operation with engineers and musicians of the B.B.C.

It is interesting to note that the American Telephone and Telegraph Co., when considering the design of music lines and amplifiers, arrived at practically the same result.

Other methods of indicating volume may be used, such as a condenser-charging peak voltmeter, or a Moullin (valve) voltmeter, but the former seems to be too much affected by the peaks, and the latter too little.

As a great deal of confusion has arisen from attempts to compare reference volume with the milliwatt at 800 p.p.s. (.78 volt on a 600 ohm line) generally used for testing trunk circuits, a slight digression with the object of discouraging any such comparison may perhaps be allowed.

The volume indicator is used to adjust amplifiers while speech (or music) is passing through a circuit. The milliwatt of steady tone is used to adjust the various amplifiers (repeaters) so that each deals with its proper share of the line attenuation. Repeater output levels are determined more by cross-talk considerations than by risk of overloading, and the milliwatt happens to be a convenient amount of testing power. Since the distortionless output of an ordinary repeater is 57 milliwatts the transmission level would have to exceed 18 dbs (above a milliwatt) before overloading would occur during test.

It is often convenient to use steady tone to test the working of voice-operated devices such as echo-suppressors or certain types of volume indicator, but it is essential that the R.M.S. value of steady tone, which produces the same effect on the device under test as reference volume speech, should first be determined.

For instance, it was found that a milliwatt through 10 db produced the same result on a certain echo suppressor as reference volume speech—not counting or droning, which may, of course, amount practically to a steady tone.

Although the type of distortion usually known as valve overloading which results in the production of grid current is generally the most important, such factors as non-linearity in valve characteristics and in transformers are partly responsible for fixing the maximum safe volume which an amplifier can transmit.

Underground Cables.—The size of conductor and loading will obviously be dependent firstly on the minimum value of the cut-off frequency and, secondly, on the maximum permissible repeater section attenuation. At the present time there is in this country a considerable length of circuit involving 40 lb. conductors, 22 or 16 *m*H loading coils and 2,000 yards spacing; although it must not be overlooked that certain unloaded conductors are giving great satisfaction on some routes. The above loadings involve cut-off frequencies of 7,700 and 9,000 p.p.s. respectively, thereby catering satisfactorily for transmission of frequencies up to 6,000 and 6,800 p.p.s. It has been decided that as soon as practicable transmission circuits with a coil spacing of only 1,000 yards shall be set up, so as to obtain a cut-off frequency of 11,000 p.p.s. and transmission up to 8,000 p.p.s.

In the case of the existing 16 *m*H loaded circuits, screened pairs are employed, metalised paper strip being used for this purpose. By this means cross-talk attenuation between adjacent pairs is greater than 100 dbs for frequencies up to 7,000 p.p.s. or more. For the ordinary multiple twin cables the pair-to-pair cross-talk attenuation with 22 *m*H loading had an average value of 90 dbs and worst values of 84 dbs. The shields can, however, be rendered unnecessary by such means as segregation of the music pairs, closer spacing of coils and a restriction on the repeater section attenuation lengths. In certain new cables in Europe shielded pairs are in use, while in America segregation and closer coil spacing are preferred.

The loading coils have cores of a powdered alloy of high permeability, giving eddy current and hysterisis factors of a very small order. The latter is especially advantageous in reducing to a negligible quantity the effect of current magnitude on the circuit loss. The phantom circuits are not used in any circumstances and in this country side circuit transformers are also cut out.

Typical attenuation frequency and impedance frequency curves for the 40 lb., 16 *m*H loaded circuits with 2,000 yards spacing are shown in Figs. **2** and **3**.

In regard to attenuation it will be seen that below, say, 2,000 p.p.s. the curve falls, the shape approaching that for unloaded conductors and it will be found that the useful effect of loading is

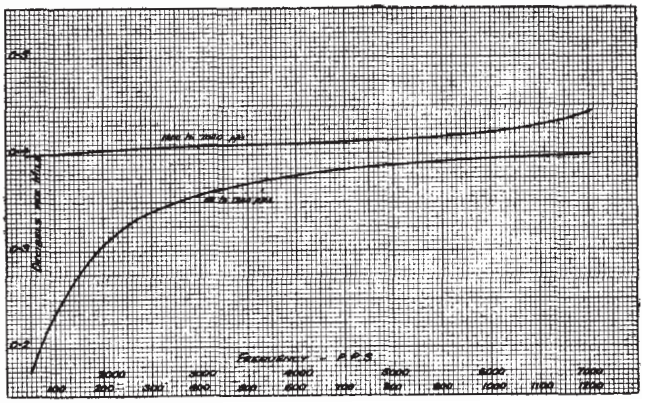


FIG. 2.—ATTENUATION FREQUENCY (CALCULATED) 40 LB. CONDUCTORS LOADED 16 *m*H AT 2000 YARDS.

completely lost for frequencies below about 100 p.p.s. Here, of course, ωL is negligible compared with R. Above 2,000 p.p.s., the usual type of lumped loading curve becomes manifest, although the increase of attenuation on a 50 mile length of circuit up to, say, 70% of the cut-off is only 1 db.

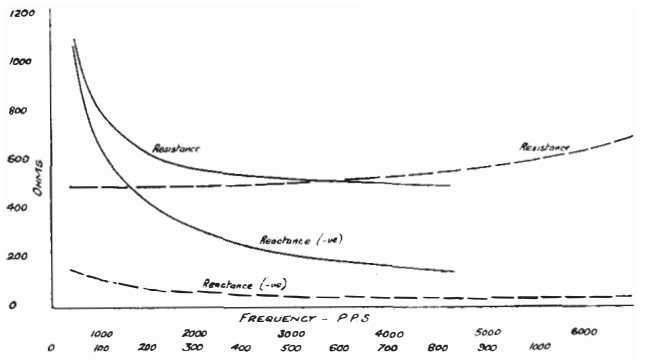


FIG. 3.—IMPEDANCE OF 40 LB. CIRCUITS, LOADED 16 *m*H AT 2000 YARDS. FULL LINES 50-800 P.P.S. BROKEN LINES 800-6500 P.P.S.

Broadcast Repeaters.—The principal factors involved in the design of a suitable type of repeater are:—

(*a*) A uniform gain over the frequency range, say, 35 p.p.s. to 8,000 p.p.s. and means for gain frequency equalisation to cope with the line attenuation frequency characteristic.

(*b*) For volumes extending from the loudest passage down to those which are about 20 db weaker the gain should be constant.

(*c*) Depending upon the cross-talk conditions prevailing in the broadcast system, the repeater output should be fixed at a certain volume, in relation to, say, reference volume.

(*d*) Distortion, additional frequencies, transients, etc., should obviously be negligible.

Dealing now with these in more detail we have :—

(*a*) By the use of the high permeability alloys such as permalloy, mumetal and radiometal for the transformer cores it is relatively easy to obtain sufficiently high inductance for the faithful transmission of the low frequencies, while experiencing no deleterious effects from capacity at the higher frequencies. The design adopted (Fig. 4) shows input and output transformers with resistance-capacity coupling at the interstage, two stages being employed with the nominal maximum gain of 38 dbs.

The equalisation scheme shown consists of the series resistance-condenser combinations (*x*) for the low frequency correction, a well known form of resonant circuit (*y*) and condenser arrangement (*z*) for the high frequencies. By these means flat gain characteristics or gain equalisations with a tolerance of ± 0.2 db are generally possible. Gain adjustment is effected by the potentiometer and taps on input transformer and interstage resistances. The minimum gain obtainable is 6.5 dbs and the adjustment is in steps of 1.5 dbs.

(*b*) Gain variation for different current strengths will not only complicate the question of setting up circuits but involve the production of harmonics due to the non-linear amplification. This phenomenon is usually associated with the low frequency end, where in transformers the product ωL is relatively small, not only due to ω but also for feeble currents the permeability falls and L is reduced. For higher frequencies the value of ω masks the possible variations in L. In existing telephone repeaters this feature is evident below about 150 cycles, such that at 50 cycles the gain may be reduced by 12 dbs when the input current falls by 20 dbs. This variation has to be avoided in the broadcast repeater, usually by increasing L to a value higher than might be necessary if currents were always large. Therefore copper losses in the output transformer and the effect of magnetic leakage are increased.

In the design shown which has been developed by the Department, some of these difficulties are removed by the push-pull feature, while for 30 dbs variation in current strength the change of gain is less than 0.5 db throughout the frequency range of 50 to 8,000 p.p.s.

In general, however, the effect of the current in the loading coils may predominate over that in the repeater. From the following table it will be observed that in a circuit consisting of 90 miles of 40 lb. cable, loaded with 22 *m*H at 2,000 yards and with three repeaters of the design shown in Fig. 4, the overall effect was quite negligble :—

Frequency P.P.s.	Overall Transmission Gain, dbs. in circuit for input current of level (dbs.)			
	0	− 10	− 20	− 30
35	10.5	10.6	10.9	10.8
100	11.6	11.8	11.9	11.9
2000	11.3	11.5	11.5	11.5
6000	11.2	11.8	12.0	12.2

(*c*) Tests were made on unshielded circuits with light loading and on the unloaded pairs in two typical cables and it was found that at the cable termination the volume of cross-talk from other adjacent circuits which might be expected is of the order of 80 dbs below reference volume. Furthermore, it was considered that in quiet surroundings the minimum signal to noise ratio should be not less than 60 dbs. The latter figure has of course to take account of a 40 db change in broadcast signal strength, in conjunction with a satisfactory maximum value of cross-talk or noise background.

Under these conditions and since the worst relative disturbances are speech, cross-talk or ringing, and assuming the relevant circuits are transmitting in the same direction, it follows that the volume of the loud broadcast signal should never fall below − 20 dbs in relation to reference volume. Whence it is seen that with an assumed value of as much as 30 db attenuation between repeater stations the repeater output volume should have a normal maximum value of + 10 dbs in relation to reference volume. It is considered that these conditions will, from the stand-

point of cross-talk, ensure satisfactory broadcast transmission without interfering with the ordinary telephone circuits. The conclusions are confirmed by experience with temporary underground music circuits where the attenuation length between certain repeater stations is at present too high for the volume the repeaters will handle.

In these circumstances therefore a broadcast repeater to handle 10 dbs above reference volume, with existing plate voltage supplies of 130 or 150 volts and using ordinary valves, must be of the push-pull type.

of permalloy core input and output transformers and resistance-capacity interstage coupling. It was found that the magnitude of harmonics when the former was delivering sensibly sinusoidal power of 170 milliwatts was slightly better than when the latter was delivering only 1.7 milliwatts, which is 20 dbs less. The value of the total harmonic content was in each case about 38 to 40 dbs below the level of the fundamental.

In a comparison of these two types it should generally follow that the push-pull type has the advantage, not only in partially or wholly eliminating the even harmonics of the valve

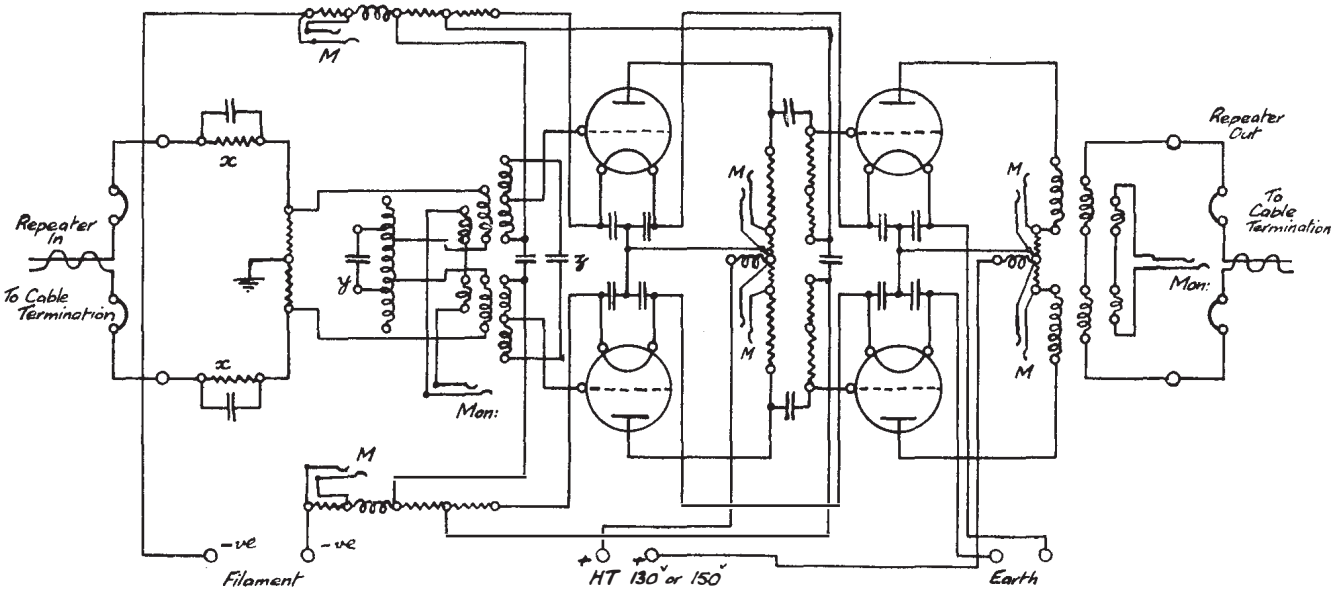


Fig. 4.—Repeater for Broadcast Transmission Circuits. M—measuring jacks. Mon—monitoring jacks.

(*d*) Both the types of distortion dealt with under headings (*a*) and (*b*) are easily prevented. Under (*c*) it is interesting to note that the B.B.C. generally use amplifiers of the non push-pull type, but with plate voltages of 300 volts, where the power to be handled is smaller than in the case of the line repeaters. With small grid priming voltages the even harmonics due to curvature of the valve characteristics are thereby rendered negligible in value.

A test to determine the magnitude of harmonics generated in the repeater with different output powers was made, especially in regard to a comparison between the push-pull and the non-push-pull types. The former was of the design shown in Fig. 4, while the latter consisted

curve, but also in the case of the output transformer where the direct current flux can be made practically negligible. It appears that the output transformer is the main culprit in the generation of harmonics, for valves which were not well balanced with each other could be introduced without causing any perceptible change. An interesting test on these lines was made by the B.B.C. where it was found that with amplifiers of their own design the quality of music reproduction was best in the case of a push-pull type of repeater in which the output stage arrangement involved no transformers. In order of merit the other types were as follows: second, non-push-pull without transformers; third, push-pull with transformer; and last, non-push-pull

with transformers. In all these cases the plate voltage was 300 volts.

Apart from the steady state forms of distortion, that is to say, imperfection of frequency response and non-linear distortion, transient effects in lines and transformers are certainly present, both at very high and very low frequencies, but, fortunately, with the distances and numbers of repeaters involved in this country the transient effects can probably be safely neglected. The subject is being investigated, however.

In conclusion, the authors wish to emphasise that the type of repeater which has been evolved is capable of giving a much higher output than the ordinary telephone repeater. There are two main reasons for this:—First, the existing main cable system had to be adapted to the rapidly expanding broadcasting service and this sometimes meant higher attenuation between repeaters than would be aimed at when starting *de novo*. Second, where new cables provide opportunity for laying out the music circuits to the best advantage it is well to have a margin of power in the repeaters to meet a possible demand for still higher quality of transmission. The line amplifiers used by the B.B.C. can deal with power output far above that which they normally transmit at present.

DEVELOPMENTS IN BROADCAST RADIO RECEIVING APPARATUS.

PART II.

A. J. GILL, B.Sc., M.I.E.E., M.I.R.E., and A. G. McDONALD, A.C.G.I., B.Sc., A.M.I.C.E.

THE outstanding event of the last few weeks in broadcasting circles has been the annual Radio Exhibition at Olympia. Speaking generally, it can be stated that while nothing of unexpected novelty appeared among the exhibits there was a general improvement in design and manufacture, both in component parts and in complete equipments.

A pleasing feature is the tendency of manufacturers nowadays to publish actual figures for the performance of their apparatus. The manufacturers of the better-class components are beginning to see the advantages of having their products tested by a reputable laboratory, such as the National Physical Laboratory, and publishing the results of the tests. This is all to the good and cannot fail to have a stimulating effect in improving the quality of apparatus. Some of the radio periodicals, notably the "Wireless World," have made a practice of testing components such as gramophone pick-ups, chokes, etc., and giving the results of these tests for the guidance of their readers. This practice also serves as a useful check against makers overstating their claims for the performance of their goods.

In previous years of the Exhibition, components formed a large proportion of the exhibits. This market has now been served to a great extent by the supply of kit sets in which the whole of the components are supplied with wiring diagram and cabinet at an inclusive price. The valve manufacturers have been responsible for much of this development and several of the larger firms market kits suitable for the use of their valves. In this way the purchaser is able to acquire what is practically a factory-built set without royalty payments.

There were, however, a large number of stalls exhibiting components. One of the chief developments in this line was the number of well-designed ganged condensers available. Four or five single condensers ganged to permit single knob control were common. In practically all cases, individual adjustment of capacity (or trimming) was possible without recourse to separate trimming condensers.

Exhibits of complete receivers predominated at this year's event. The housing of the receivers was for the most part well made and reasonably decorative without approaching the rather ornate style peculiar to American receivers.

A large amount of space was devoted to Radio-Gramophone equipment and a commendable

feature was the increasing use of A.C. induction motors for driving the turntable. The universal type of motor has the advantage of being suitable for both A.C. and D.C. supplies and hence is suitable for districts at present using D.C., but which will shortly be changed to A.C. under the grid reorganisation scheme. Owing to the presence of a commutator, however, such motors are a potential source of noise and their use on A.C. systems is not to be recommended.

Gramophone pick-ups, with the exception of Celestion, Edison Bell and Brown models, appeared to follow ordinary practice. The Celestion pick-up is noteworthy in that, contrary to most other makers' practice, no attempt is made to correct for the bass cut-off in ordinary gramophone recording. The Edison Bell pick-up has an ingenious system of volume control by sliding the permanent magnet towards or away from its pole pieces. This would appear to be of use only for pre-setting to avoid overloading, as it cannot be adjusted during playing. Correcting networks to increase the bass response on gramophone reproduction were exhibited by Messrs. Gambrell, Celestion and Igranic. These devices to be effective should be designed for specific input impedances. Messrs. Gambrell have now produced a model suitable for high impedance pick-ups such as the Marconiphone.

Detectors.—Grid lead detection has always been considered to give inferior results to anode bend detection. Few receivers were fitted with the latter system of detection, as the correct biasing of the detector was considered to be a process demanding more skill than the average user possessed.

A variation of the usual values of grid leak and condenser has led to a new system of grid detection called power grid detection. The new values are 0.0001 mfd. for the condenser and 0.2 to .25 megohms for the grid leak. A high radio frequency amplification is used prior to detection and the grid swing applied to the detector valve amounts to tens of volts. A high anode potential of the order of 150 to 200 volts is used on the detector and the output can, if desired, be applied directly to the loud speaker. This system, if properly adjusted, provides an output of high quality surpassing most other methods.

There seems to be no reason why power grid detection should not be adopted even in battery-operated sets, as the resulting increase in anode current is not prohibitive. The clearer quality and better reproduction of transients due to the lowering of the time constant of the grid circuit is at once evident when the new system is fitted in a set.

Selectivity.—In the majority of cases, several tuned circuits were used to secure the necessary selectivity. In the case of sets consisting of two H.F. stages detector and L.F. stages, three tuned circuits were, with few exceptions, considered sufficient. Band-pass tuning has not as yet been widely adopted. With one or two notable exceptions, wave traps have practically disappeared. The rather haphazard effect of these traps on the tuning of most receivers is probably the reason. In the case of most wave traps marketed in previous years, the tuning coil had too great a high frequency resistance for the trap to be really effective.

The Ferranti " Regional " two-valve receiver was interesting in that two circuits tuned to the Regional and National wave-length were used. The switching arrangements were such that, when one of the tuned circuits was switched in, a wave trap tuned to the unwanted frequency was also brought into circuit.

In order to secure ganging of controls the effect of the loading due to the attachment of an aerial has been minimised by the use of a weak aperiodic coupling. This has materially assisted in securing a higher selectivity, although a reduction in input has followed. The selectivity of receivers is a subject on which makers could be a little less bashful, particularly in the case of receivers fitted with single knob control. Where multi-controls are provided, it is of course impossible to quote figures for selectivity, as the same adjustment is never obtained twice on any one wave-length. A suitable method of defining the selectivity is to state the width of the resonance curve at points 3, 10, 20, 40 and 60 decibels down from the value at the tuned frequency. The resonance curve published by one manufacturer for his sets shows that these values are approximately 10, 20, 60 and 120 kilocycles respectively. This means that two stations of equal field strength would have to be about 60 kilocycles different in frequency for one to be received without interference from the other. Interference 60 decibels below the wanted signal

is practically inaudible and would not be noticed. Interference 40 decibels below the wanted signal is apparent in the silent periods of the wanted station's transmission, but otherwise does not cause inconvenience.

Screening.—In order to stabilise radio frequency amplifiers, screening is extensively employed. Originally, a simple metal partition was employed between stages, but of late the tendency has been to screen the individual components. Individual stage screening together with separate condenser screening is used in the Osram Music Magnet Four, three cans being used for the two H.F. and detector stage. The use of ganged condenser control has no doubt led to the use of separate screening for the coils, valves, valve leads, etc. Most of the sets exhibited seemed to consist of screens, cans, etc., mounted on a metal chassis. These components are often mounted very close together, so that if faults develop, tracing the source will be rather difficult. It would seem that even for the simplest of faults, such as burnt-out decoupling resistances, a return of the set to the makers would be necessary. In all receivers now, wave changing is carried out by switching rather than by changing coils and this necessitates a symmetrical lay-out of the inductances. Placing the valves within separate tubular screens enables a symmetrical valve lay-out to be used and also has the additional advantage that the valve electrodes are removed from the field of the tuning coils. Complete screening demands that the whole of the receiver components be mounted on a metal chassis. This leads to rather more expensive mountings. In the majority of components shown, such as volume controls, switches, variable condensers, etc., direct mounting on a metal panel was not possible. There is a definite demand for the insulated type of component which is not fully met at the present time.

Mains Components and Sets.—For reasons of economy and also because of its high stage gain, the use of a pentode as the output valve appears to have been widely adopted. With the new range of tapped output transformers made by Messrs. Ferranti and Messrs. Varley a reasonable matching of the loud speaker impedance to valve impedance is possible. The fact that the high tension is derived from the mains and is often several hundred volts makes it essential that the output terminals of the set should be connected to the anode circuit of the power valve by means of a choke filter or transformer. If the choke is tapped, a position in which the high note accentuation of the pentode is counteracted by a low frequency resonance can usually be found and reasonable quality secured.

The pentode is characterised in that within the working range the anode current is determined solely by the grid potential and is not affected by anode potential. As a result, the power delivered to the anode circuit is proportional to the load impedance. Many types of loud speaker, notably the moving iron type, have an impedance which increases rapidly with frequency. With such loud speakers in the output circuit of a pentode, heavy accentuation of the high notes occurs and some kind of correcting network is necessary. One suitable form is a resistance and condenser in series shunting the loud speaker terminals. This combination gives an increasing loss with frequency and can produce a marked improvement.

With regard to grid bias, in practically all main-driven sets, this was derived from the mains. The use of a small metal rectifier was favoured in some cases, but a straight-forward potential divider was mostly in use. A good example of this system is that used in the Pye Twintriple A.C. receiver. The use of free grid bias (that is, by the insertion of resistance in the H.T. negative return) does not seem to be so popular; possibly owing to the difficulty in avoiding unwanted couplings between stages with this system.

In the bulk of the radio gramophone sets and most of the four valve sets, a substantial power or pentode output was used and it seemed evident that H.T. voltage of between 300 and 400 are now in common use. Whilst the metal rectifier was used for many sets having low H.T. voltages, in practically all cases where higher values were used valve rectification was adopted. A notable feature was the extensive choice available of combined high tension eliminators and trickle chargers. For the possessor of a battery-operated set this represents the most economical form of electrification. A commendable feature was that the bulk of these sets had a variable output tapping for screen grid potential, so that

the voltage best suited to the H.T. voltage in use could be readily obtained.

Loud Speakers.—The outstanding feature of the exhibits of loud speakers was the large number of permanent magnet moving-coil models shown. In many cases the working flux density of the air-gap was stated, and flux meters with search coils were exhibited on several stands, enabling the qualities of the magnets to be demonstrated on the spot. The question at once arises as to the permanence of these magnets. The answer is reassuring—in many cases the makers guarantee the permanence with very little loss for a number of years. Where the magnets are of cobalt steel, containing 35% of cobalt, very little is to be feared on this score. Quite satisfactory magnets are produced, however, having considerably less a proportion of cobalt, which of course tends to cheapness. The inductor type of moving-iron loud speaker, in which the armature system moves parallel to the pole faces and hence has an unrestricted movement, was shown by Messrs. G.E. Co. and Messrs. Lamplugh. The balance of tone from this loud speaker was pleasing and the reproduction of transients was agreeably crisp.

Moving-coil loud speakers in which the field current is supplied from a self-contained Westinghouse metal rectifier were surprisingly popular.

In conclusion, it may be said that the whole industry appears to be in a state of healthy development on sound lines and the progress that has been made during the last twelve months in the improvement of methods and products is a happy augury for the future.

NOTES & COMMENTS

REDUCTION IN PRICE OF JOURNAL.

THE Board of Editors has decided to reduce the price of the Journal to One Shilling per copy, beginning with the April 1931 issue, which is the first number of a new volume. In returning thus to the original pre-war figure, the Board has been encouraged to its action by the splendid response to the appeals for further support among the rank and file of the staff which the Board has been issuing from time to time during the past few years. As most of our readers are aware, the Journal is self-supporting, and while the proposal receives the hearty support and sympathy of the Council of the Institution, the Board has to bear the onus of responsibility for the success or non-success of the undertaking. We feel confident of success. We shall continue to maintain the high quality of the contents and endeavour to make the magazine still more useful to the industry than it has been in the past. If the twenty per cent. reduction in price is followed by a twenty per cent. increase in circulation we are safe, but we are not fixing such a limit to the latter. Engineers and Inspectors in the districts can help to push the sale in their sections especially among the younger members of the staff. To them, the study of the Journal contents—viewed from a mere mercenary standpoint—is surely of much better value than a large packet of cigarettes.

KEMP MEMORIAL FUND.

Many of our readers will have noticed in the Electrical Press recently the reference to Mr. H. R. and Mrs. Kempe's celebration of their golden wedding at their house at Lavethan, Brockham, Surrey, and to the announcement that the parishioners of Brockham Green, where Mr. and Mrs. Kempe have resided for over 45 years, are taking steps to recognise the many services which Mr. Kempe has rendered to the Parish by establishing a permanent memorial at Christ Church, at which he is Churchwarden and lay reader. The memorial is to take the form of a set of oak choir stalls and fittings in the Church, together with a tablet bearing a dedicatory inscription. The cost of the memorial is estimated at £175 and in response to a request by the Memorial Committee to make the proposal known among any old Post Office friends who might wish to be associated with this tribute, a circular letter was issued by Colonel Sir Thomas Purves on 31st July last. Up to the present, an amount of £36 17s. 0d. from approximately 75 subscribers has been received. In acknowledging in October this contribution the Hon. Treasurer of the Fund stated that including this amount the Fund stood at £100 and that he was hopeful that orders for the work could be placed without further delay.

Colonel Purves will be pleased to receive and pass on to the Fund Committee any further contributions to the Memorial.

COMPLIMENTARY DINNER TO MR. G. BALCHIN.

There was a great foregathering of members of the Post Office Engineering staff on Wednes-

IMPORTANT NOTICE.

Reduction in Price.

As from the 1st of April next, the price of the Post Office Electrical Engineers' Journal will be reduced to

ONE SHILLING PER COPY

POST FREE: 1/3

The Annual Subscription will be reduced to

FOUR SHILLINGS PER ANNUM

POST FREE: 5/-

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Other Subscribers, including those in the Dominions, Colonies, and Foreign Countries should order from

"THE ELECTRICAL REVIEW," 4, LUDGATE HILL, LONDON, E.C. 4.

MR. GEORGE BALCHIN.

day, 15th October, at the Florence Restaurant, Piccadilly Circus, when the many friends of Mr. George Balchin gave a complimentary dinner to him to celebrate his promotion to the rank of Executive Engineer, and also to present him with a handsome radio-gramophone set, as a mark of the high regard and esteem in which he is held in all quarters of the Engineering Department of the General Post Office. The gathering was held under the auspices of the Post Office Engineering Federation, with Mr. Charles H. Smith (Chairman of the Federation and General Secretary of the P.O.E.U.) in the chair.

Among those present in addition to the guest of the evening, were Mr. E. H. Shaughnessy, O.B.E. (Assistant Engineer-in-Chief), Lt.-Col. A. G. Lee, O.B.E., M.C. (Assistant Engineer-in-Chief), Major H. Brown, O.B.E. (Assistant Engineer-in-Chief), Mr. A. G. Tydeman (Vice-Controller, P.O. Stores Department), Lt.-Col. A. S. Angwin, D.S.O., M.C., T.D. (Staff Engineer), Messrs. J. W. Bowen, M.P., George Middleton, J.P., M.P., W. Ewart Llewellyn, O.B.E. (Chairman, National Whitley Council, Staff Side), George Chase and A. C. Winyard (Joint Secretaries, National Whitley Council, Staff Side).

A telegram expressing regret for absence owing to a heavy cold was read from Mr. E. Raven, C.B. (Second Secretary to the Post Office and Deputy Chairman of the Post Office Engineering Departmental Council). The Chairman said that Mr. Raven had looked forward to coming to the dinner and would have proposed the toast of Departmental Whitleyism. A letter of apology for inability to attend was also received from the Engineer-in-Chief, Colonel Sir Thomas F. Purves, M.I.E.E., O.B.E., who regretted absence owing to unavoidable circumstances.

The toast list included "Our Guest," proposed by the Chairman, who also made the presentation. The toast was drunk with musical honours and was received with great enthusiasm. Mr. Balchin made a characteristic reply.

Mr. E. H. Shaughnessy submitted the toast "Departmental Whitleyism," which was replied to by Major H. Brown. "National Whitleyism" was proposed by Mr. W. E. Llewellyn and Mr. J. W. Brown responded.

The speeches have already been reported in full in the various service organs.

The "Wellington Journal and Shrewsbury News," of the 27th September, has an account of the funeral of our late colleague, Mr. E. A. Lakey, Executive Engineer, Telegraph Section, E.-in-C.O., who was buried in the churchyard, Oakengates, on the 14th September. The service was fully choral and there was a large congregation, the Engineering Department being represented by three colleagues of Mr. Lakey. Among the many wreaths were one from the Engineer-in-Chief and staff, and one from Col. A. C. Booth and the staff of the Telegraph Section.

The Editor, *P.O.E.E. Journal.*

Sir,

Oct. 5th, 1929—Dr. R. V. Hansford.

Oct. 5th, 1930—R101.

The fifth of October, 1930, will be remembered sadly in this country for many years to come, and to us in the Post Office it is impossible not to associate the disaster to R101 with our own more personal loss exactly one year previously.

Is the connection between these events one of date only? I think not. If we suppress all our personal feelings of loss by the untimely death of Dr. Hansford, we still feel the loss of an officer who could serve as an ideal for all who knew him. He embodied in a high degree all those qualities of enthusiasm, initiative, leadership, energy, courage and determination which distinguish the pioneer from those who are content to do merely the work which comes before them.

Can we not also respect the same pioneering qualities in those who have been responsible for airship development in this country? Can we not, without presuming to pass judgment on the technical aspect of the case nor on the findings of the Court of Enquiry, whatever they may be—can we not still pay tribute not only to those who were lost with R101, but to all those still left who have played any part in the development of lighter-than-air-craft? If R101 had succeeded in her flight to India, we should all have felt pride in a great national achievement. Though she failed in this test, can we believe that the margin between success and failure was other than a narrow one? Most of us in a humble way have been responsible for some measure of investigation work, and are used to the experience of half-a-dozen failures to one success. If we take our disappointment at any one of those failures and multiply it by a hundred thousand we have some idea of the disappointment which must be felt by all those connected with the R101.

There is always a danger at times like these that policy may be influenced by the panic tendencies of the press. Surely it is up to all those engaged in scientific development in any direction to support a saner and more balanced attitude. To say that the R101 experiment should never have been made is to say that the dead have died in vain.

C. F. O'DELL.
19 Oct, 1930.

HEADQUARTER'S NOTES.

EXCHANGE EQUIPMENT.

The following works have been completed:—

Exchange.	Type.	No. of Lines
Cradley Heath	New Auto.	540
Southend	,,	3050
Stoneygate M.F.	,,	Main Frame
Basford	Auto Extn.	570
Hove	,,	900
Ipswich	,,	300
Temple Bar	,,	100
Boscombe	New Manual	2300
Crawley	,,	620
Merrylee	,,	1600
Silverthorne	,,	1660
Altrincham	Manual Extn.	960
Allenby & Layfield	P.A.B.X.	30
Birmingham Mental Homes ...	,,	20
Black Motley	,,	30
Bradbury Agnew	,,	Re-arrangements
Bristol Police	,,	30
M.G. Cars	,,	30
King Edward Hospital (Windsor)	,,	30
Price Taylor, Ltd.	,,	20
Widnes Corporation	,,	30
Illustrated London News ...	P.A.B.X. Extensions.	50
Vickers, Ltd.	,,	Re-arrangements

Orders have been placed for the following works:—

Exchange.	Type.	No. of Lines
Calthorpe	New Auto.	1520
Denton	,,	500
Great Barr	,,	300
Hampton	,,	920
Heaton Moor	,,	1900
Hither Green	,,	3240
Kings Norton	,,	960
London Engineering District Inter Com.	,,	300
Longford	,,	880
Merton Abbey	,,	4200
Prestbury	,,	240
Sale	,,	2900
Shirley	,,	900
Smethwick	,,	1220
Sheldon	,,	300
Solihull	,,	1500
Stockport	,,	2680
Stoneygate	,,	1860
Tile Hill	,,	200
Westcotes	,,	400
Woodley	,,	520
Woolston	,,	430
Beckenham	Auto Extns.	Excess Fee Metering
Brierley Hill	,,	,, ,,
Cradley Heath	,,	,, ,,
Dudley	,,	,, ,,

Exchange.	Type.	No. of Lines.
Hillside	,,	,, ,,
Ilford	,,	,, ,,
Leicester	,,	80 Lines & re-arrangements
Macclesfield	,,	Re-arrangements
Mitcham	,,	Excess Fee Metering
Oxford	,,	340 Lines
Preston (B'ton)	,,	970 ,,
Rainham	,,	200 ,,
Rollingdean	,,	70 ,,
Stoke	,,	Re-arrangements
Southampton	,,	Re-arrangements
Stourbridge	,,	Excess Fee Metering
Tandem	,,	Re-arrangements
Wallsall	,,	Re-arrangements
Staines	New Manual	1460 Lines
Winton	,,	2420 ,,
Bexhill	Manual Extn.	Observation Equipt.
Boscombe	,,	Observation Equipt.
Mansfield	,,	Observation Equipt.
Palmers Green	,,	800 Lines
Park Western	,,	Order Wire Equipt.
Truro	,,	240 Lines
Black Notley	P.A.B.X.	30
Bristol Motors	,,	20
Bristol Police	,,	30
King Edward Hospital ...	,	30
Lesme, Ltd	,,	30
Shell Mex (Belfast)	,,	20
Taylor & Sons	,,	20
Taunton Corporation	,,	20
Willesden Council	,,	20
Illustrated News	P.A.B.X. Extn.	50
Vickers, Ltd.		Re-arrangements
West Riding C.C.	,,	
	,,	40

Mr. J. H. Simmance, M.I.E.E.

With the retirement of Mr. J. H. Simmance on the 13th November last another of the remaining links connecting the Engineering Department with the Telegraph Service is severed. Mr. Simmance entered the C.T.O. on the 2nd May, 1885, where he spent fifteen years. In March, 1900, he passed into the Engineering Department as a Junior Clerk, where his capacity for thoroughness and mastery over detail quickly attracted attention, with the result that he was advanced directly to the rank of Second Class Engineer. In 1911 he was graded Assistant Engineer and, as such, rendered conspicuous service in connection with the valuation of the late National Telephone Company's plant, for which he received the personal commendation of the Postmaster-General. In March, 1919, he became Executive Engineer in the Telephone Section and took charge of the very anxious and important work of reconstruction—the aftermath of the great war. Notwithstanding his preoccupations at this epoch, his leisure hours were given to the Chess Club where he was accounted a valuable asset and was in great request for the various Inter-Departmental events.

On the decease of the late Mr. W. Humphris-Winny, O.B.E., on the 31st May, 1927, Mr. Simmance was promoted to fill his place as Asst. Staff Engineer in the Test Section.

The 17th November last saw a gathering of about 70 colleagues and friends assembled in the Deputation Room, G.P.O. North, to say official farewell to the subject of these few notes. Testimony was given by those whose privilege it had been to come into contact with him of the esteem and regard in which he was held. Several members of the late N.T. Coy's staff spoke of the helpful way in which J.H.S. initiated them into the mysteries of State Service.

Col. Sir Thomas F. Purves, in his usual urbane manner, then presented our friend with a Ferranti All Electric Wireless Set on behalf of friends and colleagues. A gramophone pick-up also accompanied the gift.

Mr. Simmance, in a characteristic speech, spoke of the good spirit that pervades the whole of the Engineering Department and asserted his firm conviction that it was without equal among the various government departments as regards efficiency. He admitted that he was only a recent convert to the rôle of wireless listener, but he had felt hitherto that radio did not give an adequate interpretation of music and particularly of opera. Recent scientific developments, however, had caused him to modify his views hence the selection of his first wireless set. The staffs of the London and Birmingham Testing Branches had presented him with a Ferranti Moving-Coil type loud speaker and he would be able in retirement to hear his favourite operas at their best and so the apparatus would be a constant reminder of the kindness of his friends in the Post Office.

We wish "Simmy" many years of health

and happiness and if he should take that tour around the world of which he has whispered to some confidants then we hope that it will prove to be a very pleasurable one.

G.F.T.

MR. S. A. POLLOCK, O.B.E.

An interesting little ceremony took place in the Lecture Theatre, Dollis Hill, on the 14th November, when Mr. E. Gomersall presented Mr. Pollock with an album bearing the signatures of many of his friends in the service. Complimentary speeches were also delivered by Mr. Shaughnessy, Mr. J. E. Taylor, Mr. C. Robinson, Mr. Bartholomew, Major Reid, Mr. W. D. Robinson, Mr. A. E. Harrison and Mr. E. D. Hebden. On behalf of the Research Staff, Mr. W. Cruickshank presented Mr. Pollock with a pair of loving cups. The recipient made a characteristic reply. Col. Purves sent a letter intimating his regret at not being able to be present.

LONDON DISTRICT NOTES.

Telephone Growth.—Although the telephone service has not escaped the effect of the trade depression, there is still steady growth to record. During the quarter ended September 30th the nett growth of direct exchange lines and stations was 4,532 and 6,505 respectively.

The provision of plant to meet prospective development is proceeding and the total single wire mileage of local line plant has increased to 2,685,763 miles.

Equipment is being installed in six new automatic exchanges and in addition 22 new buildings are in course of erection.

Special Arrangements.—In connection with the Indian Conference being held at St. James' Palace a special telephone installation has been provided, consisting of a suite of sections to which are connected 10 exchange lines, 26 extensions, 15 call office circuits and seven private wires. A suite of 27 telephone cabinets has also been provided. The general arrangements are similar to those provided for the Naval Conference as previously described in these notes.

At the request of one of the large West End Stores an Order Department Equipment has been installed, consisting of four tables, each equipped for ten operators and with ten incoming circuits multipled thereon. Full supervision over all operators' positions and circuits is provided by means of a Supervisor's position, and the arrangement permits of team working. It is expected that other large stores will require similar installations. Those that are first in the field will no doubt reap the greatest advances.

Voice Frequency Key Sending.—Arrangements are being made for the installation of this equipment at most of those Manual Exchanges in the London Automatic Area which are not being converted to automatic working in the near future.

Kiosks.—The work of redecorating the whole of the kiosks of the No. 1 type in the London Engineering District was commenced in the spring, and already 500 of the kiosks have been reconditioned to the familiar Post Office red and stippled stone colour. The work has been carried out systematically and with due regard to the public convenience. Since the October issue of the Journal nearly 80 kiosks of the No. 2 type, 90 No. 3, and one No. 4 have been erected and brought into service in the London area. There have also been 40 telephone cabinets in suites of 2 to 12 made up in the District workshops with the now familiar polished teak or oak fronts and folding doors and are erected at Post Offices and Railway Stations, and in two cases provided for Provincial Head Post Offices. In addition, 96 single cabinets have been reconditioned and repainted. The increase in the number of call office kiosks for the six months ended Sepember 30th was 15%. The total is now over 2,000.

Retirement. — Mr. R. Wilson, Assistant Superintendent Engineer, has retired after completing over 40 years' service, a large proportion of which was spent in the London Engineering District. Mr. Wilson was of a retiring nature and shunned all publicity, but those who worked

with him learnt to appreciate his sincerity, kindness and patience. There are few who have retired of whom it can be said more truly:—"He left only friends behind." Those friends regretted that, owing to the very serious illness of his wife, Mr. Wilson could not face a company to say "Farewell." They determined nevertheless that he should take away a token of remembrance and therefore quietly presented him with a handsome wireless set. (Mr. Wilson's late colleagues will be grieved to hear that his wife passed away within a week of his retirement).

Promotions.—Mr. T. H. Edgerton has been promoted to fill the vacancy caused by the retirement of Mr. Wilson and Mr. H. G. Peck has been promoted to Executive Engineer in charge of the Centre Internal Section. Mr. Peck was in the District some years ago and is welcomed back again.

I.P.O.E.E. Informal Meetings.—The informal meetings which are held in the Dining Room at Denman Street are amongst the most useful activities of the Institution. They are really informal and really informative. Regard is not paid to the official rank of the speaker and smoking is permitted. Members who do not attend are missing a golden opportunity for obtaining inside knowledge of a type which in many cases it would be premature to print. A typical case was the very fine paper recently contributed by Mr. H. S. Pate. In these days of specialised knowledge it is very important to find out what the other fellow is doing, unless you are going to be a one-job man all your life.

Swimming Successes.—It is not usual to report social or sports events in these notes, but in view of the extraordinary success of the London Engineering District Swimming Club it is thought that a reference is justified. The following are the principal successes during the season just ended:—

Premier Division Team League Championship.—Ellison-McCartney Cup.

Civil Service Team Championship.—Clark Cup.

Post Office Team Championship.—Gresham Shield.

Aggregate Points Competition.—Taxes Cup.

One of the members won the ¼ mile championship of the Civil Service and in this competition the L.E.D. took seven out of the first ten places. There were numerous other successes.

Greetings.—The members of the London District sends hearty greetings for the New Year to previous members now in the Provinces and throughout the world.

Silverthorn Exchange.

A No. 1 Common Battery Manual Exchange was opened for service on Thursday, November 6th, 1930. This exchange replaced the Chingford (Magneto) Exchange and at the transfer 780 exchange lines were cut over to the new exchange. In these days when transfers running into thousands of lines excite but little comment—or are only of purely local interest—unless, of course, adverse circumstances arise, this reference to Silverthorn may seem superfluous.

What then are the reasons which call for any comment? In this transfer there were exceptional conditions which will probably seldom arise again in the case of a manual opening. Particulars of the transfer may, therefore, be considered worth placing on record.

The London Automatic area is contained within a circle of ten miles radius with Oxford Circus as the centre. Chingford Exchange was situated just outside this circle on its N.E. periphery and, in accordance with the existing junction routing arrangements, calls from the majority of the London Exchanges were before the transfer routed *via* Toll "A" Exchange on a group of Toll-Chingford junctions.

The new exchange (Silverthorn) is situated just within the ten mile circle in the same locality and thus becomes part of the London Automatic network. In consequence, arrangements for routing calls from all London exchanges either direct or *via* Tandem had to be made, and a group of 25 junctions from Tandem Exchange was, therefore, provided. These junctions carry the traffic both from Manual and Automatic exchanges. Calls from Manual Exchanges pass *via* the Cordless B positions at Tandem to the C.C.I. position at the new exchange, and from Automatic *via* the Automatic Repeaters at Tandem.

The first three letters of the old exchange, viz., *Chi*ngford, are the same as those already in use in another part of the London area, viz.,

*Chis*wick. It became necessary therefore to alter the name of Chingford, and Silverthorn was selected.

We then arrive at this situation—that whereas before the transfer the calls for Silverthorn (SIL) were routed *via* Toll " A," at the transfer the calls must route to the new Silverthorn exchange *via* Tandem, and that the change must be effected without interruption. This was accomplished in the case of calls from Automatic Exchanges by an alteration of the translation on the Directors from TOL to TAN and the exceptional nature of the transfer now becomes apparent.

At the time of the opening of Silverthorn there were 22 Director Automatic Exchanges in the London Area, at which translation changes were required on no less than 410 Directors serving the 7th level, viz., the Exchanges whose initial letter is P, R, and S.

The transfer took place at 1.45 p.m. and it therefore became necessary at this hour to arrange for an alteration of the translation on the Directors to take place simultaneously throughout the London area. The arrangements were as follows:—

In each Automatic exchange, 50% of the Directors in the group in question were busied one by one, commencing one hour before the transfer, and the alteration in the translation carried out, the directors remaining busied until the time of transfer. Simultaneously with the opening of the new exchange these directors were thrown into service and the remaining 50% busied *en bloc* and treated in a similar manner, but with the exception that they were put back to service as each director translation was changed.

The directors were routined before being restored to service and a few test calls put through from each Automatic Exchange to the new Silverthorn Exchange. Only 11 men were engaged in the work of actual transfer at Silverthorn Exchange, but approximately 50 men were occupied with the transfer in the rest of the London area.

Calls from Manual Exchanges were directed to the new Silverthorn exchange by operators who were previously instructed, as from 1.45 p.m. on the day of transfer, to pass calls over the Tandem Order Wire instead of *via* Toll Exchange, the SIL translation on the Tandem 7-digit senders having been brought out previously.

Close co-operation was essential throughout the whole of the operations and, incidentally, it was necessary for all officers concerned to " synchronise " their watches with the Engineer in charge of operations at Chingford Exchange.

A.W.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

COLONIAL CORRESPONDING MEMBERSHIP.

The following grades of officials of Colonial Government Administrations are eligible for Colonial Corresponding Membership of the Institution:—

Australia.

Cadet Engineers.
Engineers, Class E, D, C, B.
Sectional Engineers.
Deputy State Engineers.
State Engineers.
District Engineers.
Supervising Engineers.

New Zealand.

District Telegraph Engineers.
Telegraph Engineers.
Technical Clerks.
Engineering Cadets.

India.

Chief Engineer, Telegraphs.
Deputy Chief Engineer, Telegraphs.
Deputy Chief Engineer, Telephones.
Directors, Telegraph Engineering.
Divisional Engineers, Telegraphs.
Electrical Engineer-in-Chief.
Asst. Divisional Engineers, Telegraphs.
Asst. Engineers, General.

India—(continued).

Asst. Engineers, Telephone.
Asst. Electricians.
Deputy Asst. Engineers, General.
Deputy Asst. Engineers, Telephone.
Deputy Asst. Electricians.
Director of Wireless.
Divisional Engineers, Wireless.
Asst. Divisional Engineers, Wireless.
Asst. Engineers, Wireless.
Deputy Engineers, Wireless.

South Africa.

Engineers (Headquarters).
Asst. Engineers (Headquarters).
Divisional Engineers-in-charge of Provinces.
Asst. Engineers.
Engineering Assistants.

Southern Rhodesia.

Engineers.
Sub-Engineers and Technical Clerks.
Officers in Charge of Automatic Exchanges.
Engineering Assistants, Grade A.

Ceylon.

Chief Engineers.
Asst. Engineers.
Divisional Engineers.
Engineers.

BOOTH-BAUDOT AWARD.

Applications are invited for the "Booth-Baudot Award" of £10 which is offered annually for the best improvement in Telegraph, Telephone or Radio Apparatus or Systems. The award is governed by the following conditions:—

1. The Award will be restricted to employees of the British Post Office.
2. Applications for the Award should be made between 1st January and 31st March, 1931, and such applications should refer to improvements made, or suggested, during the twelve months ending 31st December, 1930.
3. The Award may be withheld at the discretion of the Council of the Institution of Post Office Electrical Engineers if, after full consideration of the applications received, the adjudicators appointed by the Council are of the opinion that no award is warranted.
4. Applications for the Award, accompanied by full details of the improvement, should be addressed to the Secretary, The Institution of Post Office Electrical Engineers, G.P.O. (Alder House), London, E.C.1.

P. G. HAY,
Secretary.

December, 1930.

CENTRE AND DISTRICT NOTES.

LONDON CENTRE.

The opening meeting of the Session was held on October 21st when a record attendance, presided over by the President, Col. Sir T. F. Purves, O.B.E., M.I.E.E., saw and heard Departmental and Western Electric Co.'s films.

The films exhibited had been selected to demonstrate the educational possibilities of silent and talking films and were:—

Western Electric Co.'s films—
Finding His Voice.
Behind the Lines.
Business in Great Waters.
Characteristics of Sound.

Departmental films—
Assembling and adjusting an Automatic Dial.
Jointing a Lead Covered Cable.
Pole hole excavation.

The second meeting, presided over by Mr. E. Gomersall, O.B.E., M.I.E.E., was held on November 11th, when Mr. L. L. Tolley, B.Sc. (Hons.), A.M.I.E.E., read a paper entitled "Testing of Paper for use in Telegraph System." The paper was illustrated by a series of fine slides, many of which were coloured to show more clearly the fibres of different papers.

A good discussion followed to which Mr. Tolly ably replied.

At the beginning of the meeting, the Chairman urged upon the members the desirability of increasing the membership of the London Centre. He pointed out the value of the Institution to those who wished to keep in touch with modern development.

Informal Meetings.

The first Inormal Meeting, presided over by Mr. P. T. Wood, A.M.I.E.E., was held on Tuesday, October 28th, when Mr. H. S. Pate opened a discussion entitled " Manual v. Automatic; Some comparisons of Costs."

Mr. P. G. Hay opened the subsequent discussion and many other speakers contributed to a very interesting and instructive evening.

The second Informal Meeting, presided over by Mr. P. T. Wood, A.M.I.E.E., was held on Tuesday, November 25th, when Mr. A. F. E. Evans, Grad.I.E.E., opened a discussion before a record attendance entitled " The Development of Key Sending from " A " Positions "; the talk being illustrated by lantern slides.

The subsequent discussion was opened by Mr. W. S. Proctor, and other speakers made valuable contributions which brought out the far reaching effects of key sending.

SOUTH LANCASHIRE CENTRE.

The first meeting of the Session was held on October 13th, 1930, when the Chairman, Mr. T. E. Herbert, gave an address in which the various activities of the Engineering Department during the past year were outlined. In the course of his remarks special emphasis was laid on the necessity for an all-round decrease in Maintenance and Construction Costs.

After the meeting a number of members visited Telephone House, to inspect the Auto-Manual Equipment recently brought into use and the Blackfriars Automatic Exchange in course of construction.

The second meeting of the Session was held on November 10th, when a paper was read by Mr. A. J. Pratt, entitled " The Development of the Telephone System." This was a specially revised and adapted form of a paper under the same title read previously by Mr. Pratt before the Liverpool and North Wales Centre of the Institution of Electrical Engineers, of which he is Chairman this Session.

The paper gave an excellent review of past progress and, in addition, showed the direction in which important modifications of the telephone system might be expected.

The reading of the paper was followed by the display of a cinematograph film loaned by the Standard Telephones and Cables, Ltd., giving a comparison between their Step-by-Step Automatic System and manual systems of operation.

SCOTLAND WEST CENTRE.

The first meeting of the Session, also the first under our new Chairman, Mr. Whillis, was held on Monday, 6th October, in the Royal Technical College. The lecturer for the day was Mr. R. MacWhirter, B.Sc., and the subject " A.C. Rectification for Power Purposes." After some introductory remarks, adjournment to the Electrical Engineering laboratory was made for the purpose of demonstrating a Mercury Arc rectifier in operation. The lecture proper was delivered in the Electrical Engineering lecture room. The general problem of converting A.C. to D.C. was reviewed and possible methods of solution were discussed. Practical types of rectifiers were considered and their action explained, the Tungar rectifier being more particularly dealt with. Dry plate and electrolytic rectifiers, their theory and characteristics, were also touched upon. Efficiencies and other characteristics of the various types of rectifiers were compared with special reference to Departmental requirements.

Voltage and current relationships between A.C. and D.C. sides of a rectifier, effect of chokes and condensers, smoothing circuits, and battery loads were also treated and a visual demonstration by oscillograph of current and voltage waves was given.

The lecture concluded with a review of progress towards the ideal rectifier and an expression of thanks to the College Authorities and Professor Parker Smith for placing the lecture room and apparatus at the disposal of the Institution, and to Dr. M. G. Say and others who kindly assisted in preparing and giving the demonstration.

H.C.M.

NORTHERN DISTRICT.

Annual Dinner and Presentation to Mr. J. R. M. Elliott, M.I.E.E.

A memorable gathering representative of all

ranks in the Northern Engineering District met on Saturday, the 11th October, at the County Hotel, Newcastle-on-Tyne, to attend the first Annual Dinner of the District and to take official leave of Mr. J. R. M. Elliott, M.I.E.E., the retiring Superintending Engineer. The function was not only unique in the history of the Northern District on account of its size and representative nature, but the occasion marked the first visit of the Engineer-in-Chief, Sir T. F. Purves, to a local social gathering.

In addition to Sir Thomas Purves and Mr. Elliott, the guests of the evening included Mr. F. Ferguson, Postmaster-Surveyor, Newcastle-on-Tyne; Mr. J. D. Taylor, Superintending Engineer, Edinburgh; Mr. J. M. Shackleton, Superintending Engineer, Preston; Mr. J. W. Atkinson, Superintending Engineer, Leeds; Mr. C. Whillis, Superintending Engineer, Glasgow; Mr. J. D. W. Stewart, District Manager, Newcastle; Mr. Tattersall, Assistant Superintending Engineer, Edinburgh; Mr. J. K. A. Nicholson, B.B.C., Newcastle; Mr. J. B. Purves, G.E.C., Newcastle, and Mr. E. C. Brooks, Standard Telephones & Cables, Ltd.

After dinner, Sir Thos. Purves proposed the health of Mr. Elliott, and in a felicitous speech, backed by an apparently inexhaustible repertoire of stories, the Engineer-in-Chief endeared himself to the assembly with his homely geniality and the sincerity of his tribute to Mr. Elliott. He said that Mr. Elliott's retirement had deprived him of a wise counsellor, an open-minded advisor, and a zealous officer, who would be difficult to replace. At this point Sir Thomas could not resist the temptation to glance at Messrs. Elliott and Baldwin and hazard the opinion that Mr. Elliott's full suit of armour might prove difficult to fill. Mr. Elliott, continued Sir Thomas, had fully maintained the status, dignity, and reputation of the Department in a great industrial area. He had been a loyal, zealous and efficient officer and he retired with the love, esteem and regard of his staff. Sir Thomas wished him many years of happiness and good health in the rest which he had so well earned.

In supporting Sir Thomas, Mr. A. Cook said that Mr. Elliott had endeared himself to every member of the staff from Pot Boy to Engineer. He was glad to take this opportunity of acknowledging the indebtedness of the staff for the many kindnesses they had received from Mr. Elliott, who had followed with credit and distinction a succession of able men.

Mr. Jas. A. Motyer considered Mr. Elliott's parting as a great loss. Mr. Elliott was retiring under the happiest auspices. He enjoyed good health, his children were well placed, he had many interests to absorb his activities and he was surrounded by a circle of staunch friends. Mr. Elliott had a long and distinguished record of which any man might be proud, but surely the greatest achievement was to retire after 47 years' service with the assured respect and warm affection of every member of his staff.

Mr. J. B. Croney also supported the toast.

Before calling upon Sir Thomas to present Mr. Elliott with a solid silver tea and coffee service and a handbag for Mrs. Elliott, the Chairman, Mr. F. G. C. Baldwin, M.I.E.E., took the opportunity of saying that in his relationship with Mr. Elliott they had never been at cross purposes, their acquaintance had been both intimate and cordial; this was probably due to Mr. Elliott's equable temperament. The handbag was being presented to Mrs. Elliott to mark the gratitude of the staff for the many kindnesses and uniform consideration which she had always shown to the staff.

In acknowledging the gifts of the staff, Mr. Elliott, who was received with musical honours, said that no words could express adequately his gratitude for the tokens of kindness as represented by the presents. The Engineer-in-Chief's action in travelling a distance of 300 miles after a strenuous week's work was characteristic of his nature. Mr. Elliott said that the welfare of the staff had always been one of his chief concerns. The success of the District had been due to the spirit of "camaradie" which permeated the staff. If the country were searched no force more competent and more loyal could be met with. The Clerical staff he had always held in the highest regard and examining officers from the Headquarters staffs had repeatedly complimented him upon the clerical work. For the Engineering Officers he had nothing but the highest praise. Mr. Baldwin had been a tower of strength. He had always been a pleasant assistant, a very hard worker, and all his work had been thoroughly and

efficiently done. The Engineer-in-Chief might rest assured that the future control of the District was quite safe in the hands of Mr. Baldwin and Mr. Bramwell. The Local Centre of the I.P.O.E.E. had been particularly successful and had enjoyed the distinction of 100% membership for several years, due largely to the enthusiasm and untiring energy of the local secretary, Mr. A. C. Smith.

The workmen of the District were second to none in the country. According to the costing figures issued periodically, the Northern District holds an unassailable position. Since 1924, the District had consistently held the premier position and this performance was a matter of pride. This position was achieved by close and constant supervision and by encouragement and tuition of the staff on one hand and on the other by conscientious workmen backed by a spirit of loyalty towards their supervisors. It was a great pleasure to know that he had so many good friends in the service and particularly in the Northern District. He expressed the hope that each one might enjoy the best of health and that the future might bring the best of luck.

Before moving a vote of thanks to Sir Thomas Purves, the Chairman thanked the members of the Committee with Mr. F. Johnston as secretary for the admirable arrangements made in connection with the function.

Sir Thomas replied to the vote of thanks in a characteristic manner to the delight and merriment of the company.

The musical items were extremely well rendered by local professional talent, with Mr. F. J. Shadforth as hon. accompanist.

SOUTH WALES DISTRICT.

John Henry Haynes.

Mr. J. H. Haynes, Assistant Superintending Engineer in the South Wales District, retired from the service at the end of August. Entering the service as a telegraphist at Gloucester forty-five years ago, he went over to the Engineering Department at Cardiff in 1892. Mr. Haynes was made Engineer 2nd Class in 1899 and Engineer 1st Class in 1907, filling positions successively in the North Eastern, Scotland East, South Eastern and South Midland Districts. In 1924, he returned to Cardiff as Assistant Superintending Engineer, thus completing his Post Office career in the same District in which he commenced it. During his long period of service Mr. Haynes has seen all the modern developments in the work of the Engineering Department and he has been associated at different times with many important works. His long spell of service in charge of the Guildford Section included the period of the Great War, during which the normal responsibilities of the position were seriously added to by frequent urgent demands for special work which had to be carried out by a much-depleted staff and by the fact that Aldershot lay within the Section. However, Mr. Haynes was equal to the occasion and came through this trying period with conspicuous success. The years immediately following Mr. Haynes's return to South Wales in 1924 were full of activity, conversions of the telephones to automatic working taking place at Swansea, Gloucester and Cheltenham, while the former automatic system in Hereford was replaced by standard step-by-step equipment.

By his courteous and amiable disposition, Mr. Haynes had made himself a universal favourite with all ranks of the staff and his departure was sincerely regretted. He was a loyal and conscientious colleague with a high conception of duty, who never spared himself in the matter of hard work. His counsel based on wide experience was valuable and was freely at the service of all who sought for it.

At a meeting in the District Office at Cardiff on 16th October, Mr. Terras on behalf of the staff in the District presented Mr. Haynes with a cheque as an expression of their esteem and good wishes. Mr. Haynes intends to spend this partly in purchasing some books of reference to assist him in the pursuit of the literary studies in which he has always been deeply interested and partly in going towards the cost of a gold watch.

Walter Scott.

Mr. Walter Scott, Executive Engineer in charge of the Technical Section at Cardiff, who retired on 31st July, had the unusual distinction of having spent 43 out of his 47 years of service

in the South Wales District. Entering the Post Office service at Pontnewydd in Monmouthshire in 1883, he went to Cardiff three years later and in 1898 transferred to the Engineering Department in that city. After short periods of service in Newmarket and Salisbury, Mr. Scott returned to South Wales in 1902 to take charge of the Carmarthen Section. After two years spent in Carmarthen, he came back to Cardiff, where the remainder of his official life was spent. Mr. Scott reached the rank of Assistant Engineer in 1911 and of Executive Engineer two years later, the latter promotion carrying with it the charge of the Technical Section in the District Office, a position which Mr. Scott filled with distinction for a period of seventeen years.

Mr. Scott's official activities ranged over every class of work and when an awkward technical problem arose he was generally able to give valuable advice from the store of his own experience. Among his outstanding qualities may be mentioned his clear perception of the fundamental importance of economic considerations in plant design. Mr. Scott's genial nature made him a favourite with his colleagues, and the absence of his familiar figure from the District which has known him for so many years has created a very definite gap.

The Staff of the District have marked the occasion of Mr. Scott's retirement by presenting him with a settee and two armchairs to express their good wishes and the esteem in which they held him.

NORTH WALES CENTRE.

The 1930-31 Session was opened by a meeting held at Shrewsbury on 8th October, 1930, at which the Chairman, Mr. R. A. Weaver, presided over an attendance of about 70. The paper for the day was by Mr. W. E. Radford, on " Electrolysis," and covered the many kinds of fault arising from this source, the method of location, and the various expedients which have been adopted to prevent the trouble. The paper was a very practical one, written by an officer who has been dealing regularly with electrolysis cases for some years, and epitomized his accumulation of experiences. It brought up about a dozen speakers and a very interesting discussion.

The second meeting was held on 19th November, 1930, when Mr. B. Lynn, of the Equipment Section, Engineer-in-Chief's Office, read a paper entitled " Straightforward Trunking," which had originally been read at an informal meeting in London, and which had been rewritten and brought up to date to cover the introduction of A.C. (Voice frequency) signalling. As the latter device has not yet been introduced into the North Wales District, the paper was in the nature of an introduction to new developments in trunking, which the members were hearing about for the first time. The ensuing discussion consequently took the form of a series of enquiries for more information rather than a criticism of any of the systems described. Eventually a hope was expressed, and a promise given, that an opportunity would be found for a further informal discussion on the subject at a later date, and the members departed with something very new in the way of automatic trunking devices to think about.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

Officers of Colonial and Foreign Telegraph Administrations who are engaged in Electrical Engineering Works may be admitted as Colonial and Foreign Corresponding Members respectively, after application.

Subscription payable annually in advance on 1st April in each year:

Colonial Members	... ...	£1 0 0
Foreign ,,	... ...	£1 10 0

These sums include Annual Subscription to the Journal of P.O. Electrical Engineers and the supply of all Professional Papers issued during the period covered by subscription.

Forms of application for Colonial and Foreign Membership can be obtained on application to

The Secretary,
Institution of P.O.E. Engineers,
G.P.O. (Alder House), E.C.1,

or the undermentioned gentlemen who have kindly agreed to act as representatives of the Institution in their respective countries:—

R. Badenach, Esq., B.Sc. (Melb.),
Chief Engineer's Office,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2,
Australia.

H. C. Brent, Esq.,
District Telegraph Engineer's Office,
Wellington, N.Z.

N. N. Banerjee, Esq., A.M.I.E.E. (Ind.),
Divisional Engineer, Telegraphs,
Calcutta West Division,
8, Wellesley Place,
Calcutta,
India.

A. T. Kingston, Esq., M.B.E., A.M.I.E.E.,
Office of the Chief Engineer,
Telegraphs & Telephones,
C.T.O.,
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LONG LINE TELEPHONE AND TELEGRAPH SYSTEM OF AUSTRALIA.

NORMAN W. V. HAYES and ROY JAMES ATTKINS.

Mr. Attkins has sent us a copy of the September, 1930, issue of the Journal of the Institution of Engineers, Australia, which contains a verbatim report of the above paper—No. 326, originated in the Melbourne Division of the Institution.

The following extracts will be of interest:—

HISTORY.

In 1851 the telegraph was first used in Australia, while in 1854 it was first used commercially between Melbourne and Williamstown. Telegraphic communication was established between Sydney, Melbourne and Adelaide in 1858. The first link with the outer world was established in 1872 when the line from Adelaide to Darwin was built to connect with a submarine telegraph cable extension from Java.

The telephone was introduced almost immediately after its invention and the first long distance conversation was one in 1878 between Melbourne and Ballarat. Since 1887, the telephone system has been associated with the Post Office under Government control. In 1907 a direct telephone trunk service was established between Melbourne and Sydney and, finally, in 1930, the long line telephone trunk system was connected with England and a number of European countries by the establishment of the Anglo-Australian radio-telephone service.

DEVELOPMENT OF LINE PLANT.

In comparing trunk line practice in Great Britain, U.S.A. and Australia, the authors say:

Great Britain, with short heavy routes, a thickly populated country, and severe climatic conditions, finds the solution in underground cable.

The United States, with long heavy routes, a much less densely populated country, and severe climatic conditions, finds it in aerial cable or open wires carried on mechanically strong supports.

In Australia, with long but relatively lightly loaded routes passing mostly through sparsely populated country, and much less severe climatic conditions, open wire lines with fewer poles per mile have met the case.

On many main routes in Australia, beginning in 1925, the introduction of carrier systems enabled a considerable increase in available circuits to be installed at comparatively small expenditure, but at the present time the Department has to give serious attention to the majority of its main routes. The authors then proceed to discuss the methods by which these routes can be enlarged. In general, the possible alternatives are to:—

(*a*) Reconstruct and rearrange the existing aerial routes;

(*b*) Build duplicate routes;

(*c*) Strengthen the existing routes, and run aerial cable, or

(*d*) Provide underground cable. In this connection, in a number of cases at present trunk entrance cables leading into the capital cities have been laid and loaded and they will form the beginnings of the longer loaded trunk cables which will eventually extend outwards from those cities.

Carrier Systems and their application to both telegraph and telephone services are discussed at some length, and the details are explained in

a manner eminently suited for a gathering which evidently was not composed wholly of communication engineers.

Telegraph Services.

It is interesting to find that the present trend is definitely towards the replacement of the skilled Morse telegraphist in cases such as—

(*a*) very short distances and heavy loads where pneumatic tubes are being installed;

(*b*) short distances and light loads, where the telephone is being used in place of the Morse code telegraph line; and

(*c*) longer lines with heavy loads, where printing telegraph systems of various forms are being used.

There is still a place for the telegraph service from which it is unlikely to be ousted by the telephone service, but the Morse telegraphist is gradually being replaced by the skilled mechanic as the mechanisation of the telegraph art advances. Economic considerations demand that expensive long lines shall carry the maximum number of messages and this has been met by introducing machine systems.

Machine Printing Systems.—The two forms of machine printing telegraph which are most extensively used on the Department's long telegraph lines are—

(1) The teletype system; and

(2) The Murray multiplex system.

Carrier telegraph systems are installed between Sydney and Melbourne, and also between Melbourne and Adelaide. A further system is now being installed between Adelaide and Perth, and another system is to be installed between Sydney and Brisbane.

The particular advantage of this system is that the current values transmitted per channel are comparable with telephone currents, and this makes it practicable to have the telegraph and telephone systems working on the same pole line without the one interfering with the other.

Trunk Services.

The first really long trunk telephone line erected in the Commonwealth was that from Sydney to Melbourne, which was completed in 1907, and, with a telephone repeater added, is still in use. It was run on the pole line which follows the railway line *via* Albury and is approximately 600 miles long. When this line was engineered, it was necessary to use conductors of such dimensions that with the normal speech level from a subscriber's telephone at the one end, sufficient power would still be available at the further end to operate the receiver of the called subscriber.

Ten years ago it was not practicable satisfactorily to telephone in Australia over a longer distance than that between Sydney and Melbourne, some 600 miles; whereas to-day it is practicable to speak over land lines from Cloncurry to Adelaide—a distance by line of over 3,000 miles. In the not-far-distant future this will be extended to 5,000 miles when the Adelaide-Perth line is completed and a Cloncurry to Geraldton conversation becomes possible. In 1922 the Department had some 33,000 miles of trunk channels, while at 31st December, 1929, there were 186,806 miles—an increase of 566 per cent.

Telephone Stations.

In 1915 there were 157,317 telephone instruments in Australia; in 1930 (June 30th) there were 520,169.

BOOK REVIEWS.

" The Romance of the Civil Service." By Samuel McKechnie. London, Sampson, Low, Marston & Co., Ltd. Price 6/-.

Mr. McKechnie is engaged in the Telephone Section of the Engineer-in-Chief's Office.

His first book, " The Romance of the Civil Service," presents a fine, broad, general view of the Civil Service and its history and development. The book contains much of interest to the general public and goes far to correct many erroneous impressions with regard to the work of the Civil Service. The average Civil Servant, who knows little of the problems and duties of his colleagues engaged in other Departments, will find a great deal of interesting information in the book.

The circumstances and needs which governed the setting up of the various Departments are explained and dovetailed into historical perspective with a fine understanding, and the fortunes of the various Departments are clearly traced.

Much information is given about the official lives of famous Civil Servants of the past, including Charles Lamb, Geoffrey Chaucer, Adam Smith, William Shakespeare, Addison, Steele, McAdam, Trollope, Robert Burns, and even Ralph Allen, immortalised as Squire Allworthy in Fielding's " Tom Jones." As is the case today, however, most of the great men of the Civil Service had to leave the service in order to accomplish their best work. It may be that they had merely to sacrifice the less for the greater, like the parson and his golf, or it may be there is something in the atmosphere of state service that stirs certain men to have done with routine writing work, a sort of call of the wild, as it were, something akin to the impulses that makes the young city clerk linger and watch the ships loading up in London Pool.

The book contains many fine illustrations of Service buildings in Whitehall and a chapter is devoted to the Civil Service Sports movement and the progress of the Arts movements.

The Rt. Hon. Philip Snowden, M.P., writes an interesting foreword to the book in which he expresses the sincere hope that the volume will serve not merely as a historical account of the Civil Service but will create among the general public a new interest in and a greater appreciation of a Service to which every citizen is deeply indebted.

Readers of the *Post Office Electrical Engineers' Journal* will find the chapter on the work of the Post Office Engineering Department inadequate.

" Principles of Electric Power Transmission by Alternating Currents." By H. Waddicor. London, Chapman & Hall, Ltd. Pp. 419. Price 21/-.

The increasing use of long distance lines for the transmission of alternating current power has demanded a more precise knowledge on the part of electrical power engineers of the behaviour of such lines and of the effects which they introduce when interposed between a generator or source of power and the load.

The behaviour of transmission lines when carrying currents of speech frequencies became of practical importance and engaged the attention of telephone engineers at an earlier date, and at the present time there is an ample selection available of literature dealing with the subject.

The subject of power lines is perhaps not so well served, and it is thus pleasing to note the publication of a second edition of a very useful work dealing with this branch of electrical engineering. The second edition is not very different from the earlier edition with the exception of an additional chapter on the power limits of transmission systems.

The book deals not only with the characteristics and performance of the lines themselves, but also with the economies of power transmission and the protection of lines and systems against dangerous currents and pressure rises. As regards the performance of lines, this is dealt with by two methods, firstly by localised capacitance methods of solution and, secondly,

vigorously by the use of hyperbolic functions.

A pleasing feature of the book is the number of carefully worked out examples, some occupying several pages. The reader is thus assured of being able to apply the information given to obtain practical numerical results.

The book is not only a very suitable text-book for students, it is also a work of great practical usefulness to engineers.

A.J.G.

"Handbook of Technical Instruction for Wireless Telegraphists." By H. M. Dowsett. London, Iliffe & Sons, Ltd. Pp. 487. 25/- net.

The aim of this book is to provide simple instructions for sea-going operators and others, in the general principles and practice of Wireless Telegraphy and is intended to provide a complete theoretical course for the P.M.G's certificate.

The present issue marks the fourth edition of this work, the first edition being due to Mr. J. C. Hawkhead. The present edition is completely revised and the scope of the book has been widened to meet the more exacting requirements of the sea-going operators' duties of to-day. The book, which in the earlier edition described only Marconi apparatus, now covers practically the whole range of apparatus likely to be encountered on British ships and includes very complete descriptions of apparatus manufactured by Messrs. Siemens Bros. and by the Radio Communication Company. In addition to dealing with the normal types of transmitting and receiving apparatus, chapters are devoted to auto-alarm apparatus and direction-finding gear.

The work is of a most comprehensive character and completely fulfils the object for which it is written. It can be recommended to all seeking information on marine wireless equipment.

A.J.G.

"The Elementary Principles of Wireless Telegraphy and Telephony." By R. D. Bangay, third edition revised by O. F. Brown, M.A., B.Sc. London, Iliffe & Sons, Ltd. Pp. 268. 10/6 net.

Very few persons engaged on wireless in pre-war days will be unacquainted with Bangay's work. The writing of a successful book on elementary principles is always a difficult matter as the author rarely manages to come down to the level of the reader. Bangay was particularly successful in this way and was able to retain the interest of the reader and to cover by easy stages a fairly complete outline of the subject.

In this revised edition the first 149 pages contains the original text with a few minor additions; the remainder is due to Mr. O. F. Brown. The result has been very successful and the present book constitutes a very useful elementary text-book. Among the subjects dealt with in the added section is the more detailed explanation of the principles of thermonic valves and their associated circuits, the subject of valve transmitters, radio telephony transmitters, broadcasting receivers and direction-finding. The book is a welcome addition to the elementary literature on the subject of radio telegraphy and telephony.

A.J.G.

"Easy Lessons in Television." By R. W. Hutchinson. London, W. B. Clive—University Tutorial Press, Ltd. Pp. 175. 1/9 net.

This little book gives an elementary description of the principles and apparatus used in television by the Baird system.

The book contains descriptions of much apparatus which, strictly speaking, has nothing to do with television, such as electric motors, wireless components, spark radio telegraphy and wireless receivers, and as a result the reader is liable to acquire rather a confused idea of the subject. This result is also assisted by the disjointed method of dealing with the subject.

On the other hand the book is low in price and contains a fair amount of information which will doubtless be of interest to those desiring an elementary idea of the subject.

A.J.G.

" The Theory and Design of Illuminating Engineering Equipment." By L. B. W. Jolley, M.A. (Cantab.), M.I.E.E., J. M. Waldram, B.Sc. (Eng.), G. H. Wilson, B.Sc. (Eng.), A.M.I.E.E. 709 pp. Published by Messrs. Chapman & Hall. Price 45/- net.

This book covers a very large field which is only limited in that electrical sources of light alone are dealt with. It deals comprehensively with the design of the equipment necessary to obtain good illumination and to this end physiological considerations are taken into account as far as they affect design and methods of calculation.

That the book is comprehensive will be seen from the following brief summary of the contents. After a preliminary discussion as to the nature of light, vision, and visual reactions, a section is provided dealing with methods of calculation; the distribution of light flux and intensity of illumination; and the effects of reflecting and transmitting media. The physics of light production are then considered and the various types of lamps dealt with seriatim. We thus get a full discussion of the ordinary types of incandescent lamps, vacuum and gas filled, tungsten arc lamps, carbon arc lamps and gaseous conduction lamps such as those of the neon and mercury vapour types.

The authors then deal with the types and uses of equipment for interior lighting, street lighting, flood lighting, display lighting, etc. The materials used and the details of design are fully considered with the use of reflectors, refractors and diffusers. Optical projecting systems dealt with include car headlights, searchlights, signal lights for street and railway use, and cinema projectors.

Special equipments such as are required for stage lighting, illuminated signs, studio lighting, air port lighting and many other uses are also considered, together with such auxiliary apparatus that is specially applicable to illuminating engineering and is not described in detail elsewhere.

The book is completed by a series of appendices giving useful data, lamp characteristics, tables and diagrams for use in calculations, etc.

It will thus be seen that the authors have written a book which is comprehensive in its scope, and being well illustrated and arranged it forms an excellent reference book on all aspects of electrical illuminating engineering.

J. McG.

" Telegrafia Sottomarina (Cablografia)." By Ing. Italo de Giuli. Published by Ubrico Hoepli, Milan. Price 30 lire.

This practical manual of submarine cable telegraphy is somewhat unique in that it covers the entire field of elementary theory, laying, operating, maintaining and testing submarine cables and submarine telegraph apparatus. The first section is devoted to descriptions of methods of manufacture and the laying of cables and of transmitting and receiving apparatus. Alphabets, signals and elecrical characteristics are also dealt with in a simple fashion. The second section deals with the equipment of cable stations. In the third section the principal tests used in submarine cable telegraphy are described and explained. Section four deals with multiplex working and section five is devoted to the construction, characteristics and testing of loaded cables. The book is well illustrated and will be useful not only to those actively employed in maintaining and operating submarine cables, but also to students and others who wish to obtain a general knowledge of the whole of this interesting subject.

J.J.M.

" Relays in Automatic Telephony." By R. W. Palmer, A.M.I.E.E. 192 pages. Sir Isaac Pitman & Sons, Ltd. Price 10/6 net.

The importance of the electromagnetic relay in the circuits employed in automatic switching systems can scarcely be over-estimated. Hitherto there has been a lamentable lack of information in regard to the construction, design and adjustment of such relays in the various text-books on Automatic Telephony. It is all the more pleasing, therefore, to see that Mr. Palmer has written a most useful and readable book covering this aspect of the complex art of this branch of telephony.

The first chapter is devoted to a brief description of the types of relay more commonly encountered in manual telephone systems, fol-

lowed by a detailed description of the pendant armature and pin-type relays used in automatic telephone circuits; in this connexion, Figs. 4 and 7 are particularly clear and useful. The next chapter provides a description of the contacts and springs used on relays, such problems as contact bounce and spark quench being dealt with. Then follows an account of the mechanical adjustments to which relays are subjected, the third chapter being devoted to this. Chapter IV. covers a description of the various inductive effects employed in relays of various types, such as slugged relays and high impedance relays. Special relays, such as the shunt field and pendulum bob relays, are described in the next chapter. Chapter VI. is devoted to relay design and the descriptive matter is supported by worked examples of the calculations necessary in designing a relay to fulfil a specific purpose; these form a most useful feature. The next two chapters deal with the effects of the electrical characteristics of the line upon impulsing. In the last chapter is found a consideration of the various methods used for measuring the time lags of relays and the impulse frequency of dials. Two appendixes—one giving the time lags of A.T.M. relays in various circuits and the other being an abstract from the 1930 edition of the B.E.S.A. Standard Terms and Definitions used in connexion with Telegraphs and Telephones—complete the book.

Since that portion of the syllabus of the City and Guilds examination in Automatic Telephony having reference to relays is adequately covered, the text-book should prove extremely useful not only to engineers engaged in the practical application of Automatic Telephony but also to students of the subject. W.S.P.

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